



**INVESTIGATION OF DRINKING WATER QUALITY, SANITATION-HYGIENE
PRACTICES AND THE POTENTIAL OF INDIGENOUS PLANT SEED FOR
WATER PURIFICATION IN SOUTHEAST ETHIOPIA**

By

AHMED YASIN MOHAMMED

Submitted in accordance with the requirements

for the degree of

DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL MANAGEMENT

in the

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF ENVIRONMENTAL SCIENCE

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: PROFESSOR HAMEED SULAIMAN (PhD)

July 2017

Student number: 45595291

I declare that "Investigation of Drinking Water Quality, Environmental Sanitation Practices and the Potential of Indigenous Plant Seed for Purification in Southeast Ethiopia" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.



SIGNATURE

August, 15/2016

DATE

Mr Ahmed Yasin Mohammed

Approval of Supervisor: Dr. Hameed Sulaiman

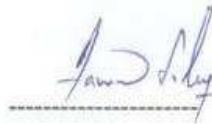
This PhD Thesis has been submitted for Examination with my approval as Supervisor

Name of Supervisor

Signature

Date

Hameed Sulaiman



15/8/2016

Abstract

Background: Access to safe water and sanitation are universal need and basic human right, but the provision of quality water and improved sanitation remains a challenge in many African countries including Ethiopia.

Objectives: The study investigated drinking water quality, sanitation-hygiene practices and the potential of *Moringa stenopetala* seed powder for the purification of water in Bale Zone, Southeast Ethiopia.

Methodology: A community-based cross-sectional study was conducted among 422 randomly selected households in Robe and Ginnir Towns. Data were collected by interviewer-administered structured questionnaires from June 2012 to August 2013. An observation checklist was used to observe the sanitary condition of water sources. A total of 71 water samples were collected using sterile glass bottles in accordance with the standard method of American Public Health Association APHA. The physicochemical and bacteriological water quality analyses were done in Addis Ababa Environmental protection and Oromia water and Energy laboratories. The efficiency of *Moringa stenopetala* seed powder for removal of turbidity, hardness, and nitrate was evaluated. Data were analyzed SPSS Version 21.0 for the window. Descriptive analysis was done for appropriate variables. Logistic regression was used to identify the factors associated with under-five diarrhea. The results were presented using adjusted odds ratio and P-value of < 0.05 was used to declare significance association.

Results: From the total sample, 401 respondents participated making a response rate of 95%. More than one third (37.9%) of the respondents were found to use pipe water. Two hundred and eighty (69.8%) of households wash storage containers before refilling and 325 (81%) of households were using separate containers for water storage. Two hundred seventy (67.3%) of the households had pit latrine. Prevalence of childhood diarrhea was found to be 50.1%. From the logistic regression model, those households having access to clean water source are 68% less likely to have under-five diarrhea, the households having clean storage of drinking water are 45% less likely to have under-five diarrhea in their home, and those households having poor latrine sanitation are 68% more likely to have under-five diarrhea in their home. Seed powder of 200mg/l *Moringa stenopetala* reduced the Nitrate concentration doses from 5.49mg/l to 8.18mg/l, a 75mg/l was reduced the turbidity from 4.49NTU to 1.07 NTU. A total hardness of 427 was reduced by 7.8% after treatment with powder seed of *Moringa stenopetala*.

Conclusion: Prevalence of childhood diarrhea was high and it is associated with lack of access to a clean water source, poor sanitation of drinking water storage and latrine. Prevalence of open field defecation was remarkably high. The iron content of drinking water was above the range of World Health Organization standards. *Moringa stenopetala* seed powder has efficiency in the reduction of total and faecal coliform, turbidity, hardness and nitrate level in drinking water

Recommendation: Health education on water handling, sanitation and low-cost effective water treatment methods like Using *Moringa stenopetala* seed should be practiced at the household level.

Keywords: Drinking Water Quality, Sanitation-Hygiene, water purification, Indigenous Plant Seed.

Abbreviations and Acronyms

ADF	African Development Fund
AMCOW	African Ministers Council of Water
BH	Bore Hole
CFU	Colony Forming Units
CSA	Central Statistical Agency
EDHS	Ethiopia Demographic and Health Survey
FDRE	Federal Democratic Republic of Ethiopia
FSM	Fecal sludge management
GTP	Growth and Transformation Plan
HE	Health Extension Workers
IDRC	International Development Research Center
IFRC/RCS	International Federation of Red Cross and Red Crescent Societies
ISC	Improved Sanitation Coverage
ISWM	Integrated Solid Waste Management
IWRM	Integrated Water Resource Management
JMP	Joint Monitoring Program
MDGs	Millennium Development Goals
MOH	Ministry of Health
MoWE	Ministry of Water and Energy
MPN	Most Probable Number
NTU	Nephelometric Turbidity Meter Unit
R	Reservoir
RWSS	Rural Water Supply and Sanitation
TDS	Total Dissolved Solid
SNPPR	Southern Nations, Nationalities and People's Region
SPSS	Statistical Package for Social Sciences
UNICEF	United Nations International Children's Emergency Fund
WASH	Water Sanitation and Hygiene
WHO	World Health Organization
SDG	Sustainable Development Goals

Acknowledgements

It is indeed a gift, much undeserved for that matter, from Allah that I have been able to accomplish this work. He had brought the right people at the right time so that I would be able to carry on and complete this work. First and foremost He has blessed me with a wonderful Supervisor, Dr. Hameed Sulaiman at Sultan Qaboo University, Oman and Visiting Faculty at Addis Ababa University, Ethiopia. His kindness, optimism, and encouragement have meant so much to me. Had it not been for his careful and meticulous review of the work, this paper would not have been what it is now. His insightful and accurate comments have been both an encouragement and a frame of reference for the work. I am deeply grateful for all his kindness and support. I am also indebted to Professor Tenalem Ayalew of Addis Ababa University, Department of Earth Sciences, for his review of work and comments.

I Express my gratitude to Assistant Professors Mr.Kedir Hussein, Mr. Muhammedawel Kaso, Mr. Tomas Benti, Mr. Negassa Dida and Mr. Daniel Bogale of Madda Walabu University for the review of the work, detailed comments and taking time to go through the work with me. I am also indebted to Madda Walabu University, Ethiopian Ministry of Education and UNISA for their support. I would like also to thank my family, particularly my Mother Zehara Ali, Wife Meseret Eshete, Daughter Lula Ahmed and brother Dr. Engg. Bizuayehu Yasin. Finally, I dedicate this work as a memory for my father Yasin Mohammed, mother Aregash Mohammed and sister Habiba Yasin. I hope that I would become a better care taker of this Precious Allah gave planet, for if anything this work has done, it has made me feel how much I do not know.

Ahmed Yasin Mohammed

July 2017

Lists of Figures

Figure 1: Trends in water supply and sanitation coverage in Ethiopia, comparing JMP with MoWE estimates and projections, from 1990 to 2015.....	5
Figure 2: Trends in water supply and sanitation coverage in Ethiopia, comparing Joint Monitoring Program (JMP) with MoWE estimates and projections, from 1990 to 2015.....	6
Figure 3 Regional disparity in water access and Latrine Coverage, 2009	7
Figure 4 Oromia National Regional State River Basin.....	12
Figure 5 Map of Bale Zone	14
Figure 6 Bale Zone River and River basins	15
Figure 7 <i>Ten years trend of potable water in percent, Bale zone, Ethiopia, 2014</i>	19
Figure 8 : The tapped springs of Robe Town water sources	19
Figure 9: Madda Walabu University Reservoir	20
Figure 10 Photo of Borehole I of Robe Town, 2012	20
Figure 11 Photo of Reservoirs number 2 of Robe Town (Photo taken 2014).....	21
Figure 12 :Water scarcity at study area (taken during survey period)	22
Figure 13: Schematic map of Ethiopia's river basins. <i>Source: Nuru, 2012.</i>	29
Figure 14: The F-diagram for fecal-oral disease transmission (Curtis, Cairncross)	40
Figure 15: Causal pathways linking lack of water with food insecurity	53
Figure 16 : The Main Pathways of Human Exposure to Pathogens in the Aquatic Environment	54
<i>Figure 17: Consumption and Income Effects</i> (Sources: Christophe Bosch <i>et al.</i> Water, Sanitation, and Poverty, 2001).....	57
Figure 18: Trends in access to improved water sources coverage, in Ethiopia (1997-2012 GC). Source MoH & MoWE, 2013; Source; MoH& MoWE, 2013.....	65
Figure 19: Trends in access to improved sanitation coverage, in Ethiopia (1990-2004EC) Source; MoH & MoWE, 2013.	66
Figure 20: Estimated trends of use improved drinking water sources in Ethiopia. Source: WHO/UNICEF JMP, 2013, 2014, 2015. Source: WHO/UNICEF JMP, 2013, 2014, 2015....	67
Figure 21: Estimated trends of use of sanitation facilities in Ethiopia Source: WHO/UNICEF JMP, 2013, 2014, 2015. Source: WHO/UNICEF JMP, 2013, 2014, 2015.....	68

Figure 22: Conceptual framework Sanitation-Hygiene Practices of consumers.....	90
Figure 23: Conceptual framework of factors affecting drinking water quality and purification using <i>moringa stenopetala</i> seed powder	91
Figure 24: Location map of the study towns.....	93
Figure 25: <i>Moringa stenopetala</i> tree in the study area and the seed.....	98
Figure 26: Distribution of sanitation of latrine by family household size In Ginnir and Robe town	108
Figure 27: Solid Waste Management system at household level at the study area.....	109
Figure 28: Turbidity values of water samples selected from Ginnir and Robe Town,	115
Figure 29: Concentration of iron, sulfate, and Nitrate in Robe Borehole sample waters	117
Figure 30: Turbidity measurements in springs, borehole and reservoirs at Robe and Ginnir towns of Bale Zone, Southeast Ethiopia, 2012.	118
Figure 31: TDS at three Robe reservoirs, 2012	119
Figure 32: Nitrate concentration in selected water samples of Robe and Ginnir towns, 2012.	119
Figure 33: Total dissolved solids in selected water sources in Robe and Ginnir town, 2012.	120
Figure 34 Distribution of Iron Concentration in Robe and Ginnir Towns Water Sources, 2012	121
Figure 35: Sulfate concentration in selected water sources in Robe and Ginnir town, 2012.	121
Figure 36: TDS versus EC of selected water samples, 2012	124
Figure 37: Turbidity Removal efficiency of <i>Moringa stenopetala</i> seed in selected water samples in the study area, 2012	126
Figure 38: Nitrate removal efficiency of <i>Moringa stenopetala</i> seed in selected water samples in the study area, 2012	126
Figure 39: Total Hardness Removal efficiency of <i>Moringa stenopetala</i> seed powder in selected water samples in the study area, 2012.....	127

Lists of Tables

Table 1: Oromia Water Resource Management Bureau five years urban water coverage from 2006-2010.	16
Table 2: Principal sources of drinking water for Bale Zone, Ethiopia, 2010.....	17
Table 3: Access to potable water in Different Woredas of Bale Zone, 2014.....	17
Table 4: The ten years period water supply beneficiaries and access to potable water in Bale zone, Ethiopia, 2014	18
Table 5: Distributions of River Basin in Ethiopia.....	29
Table 6: WHO Water accessibility Indicators	32
Table 7: Types of sources of drinking water and sanitation	33
Table 8: Water-related targets in the Growth and Transformation Plan.....	34
Table 9: Rural and urban water supply coverage for Ethiopia, 2010.....	35
Table 10: Socio-demographic characteristics of respondents, Robe and Ginnir town, December, 2013. (n=401)	101
Table 11. : Water handling practices related to collection and transportation in Robe and Ginnir towns of Bale Zone, South East Ethiopia, 2012	103
Table 12: Water handling practices related to storage and usage by households of Robe and Ginnir towns of Bale Zone, South East Ethiopia, 2012.....	104
Table 13: Sanitary condition of six protected springs found in Robe and Ginnir Towns of Bale Zone in 2013	106
Table 14: Practices related to liquid and solid waste management and personal hygiene in Robe and Ginnir town, December 2013 (n=401).....	107
Table 15: Distribution of Factors associated with Under Five diarrhea at Robe and Ginnir towns of Bale Zone, South East Ethiopia, 2012	112
Table 16: Characteristics of water sources taken for physicochemical analysis from Robe and Ginnir towns of Bale Zone south East Ethiopia.....	114
Table 17: Mean Distribution of physical Quality parameter of drinking water in Robe and Ginnir towns of Bale Zone South East Ethiopia.....	115
Table 18: Mean Distribution of Chemical Quality parameter of drinking sample water from spring in Robe and Ginnir towns of Bale Zone South East Ethiopia, 2012.....	116
Table 19. Mean Distribution of Chemical Quality parameter of drinking sample water from selected boreholes in Robe town of Bale Zone South East Ethiopia.2012.	117
Table 20 Mean Distribution of Chemical Quality parameter of drinking sample water from reservoir in Robe town of Bale Zone South East Ethiopia	118

Table 21: Mean Values of Physicochemical parameters by types of water sources in Robe and Ginnir Towns, 2012	120
Table 22: The average values of Physicochemical parameters of selected water samples by World Health Organization standard	122
Table 23: Correlation coefficient between Physicochemical quality parameters of drinking water at Robe and Ginnir Towns of Bale Zone, Southeast Ethiopia, 2012	122
Table 24: Hardness concentration, TDS and EC of selected water samples from springs and reservoirs at Ginnir and Robe Towns, 2012.	123
Table 25: Bacteriological water quality analysis Public Fountains in Robe town result	124
Table 26: Bacteriological water quality analysis Public Fountains in Ginnir town result	125
Table 27: Correlation Matrix:	177

Table of Contents

Abstract	I
Abbreviations and Acronyms	II
Acknowledgements	III
Lists of Figures	IV
Lists of Tables	V
Chapter 1: Introduction	1
1.1. Background	1
1.2. Statement of Problem	2
1.3. Significance of the study	7
1.4. Rationale of the study	7
1.5. Scope of the study	9
1.5.1. The Profile of Ethiopia	10
1.5.2. Profile of Oromia Region	11
1.5.3. Profile of Bale Zone	13
1.5.4. Demography	13

1.5.5. Drainage system of Bale Zone	14
1.5.6. Overview of Water Supply of Oromia Region and Bale Zone	15
1.5.7. Ten years trends in potable water coverage of Bale zone	18
1.5.8. Water sources of Robe Town.....	19
1.5.9. Reservoirs and Distribution System of water in Robe town	20
1.6. Aims and Objectives of the study	23
1.6.1. Specific objectives	23
1.6.2. Research Questions	23
1.6.3. Data Collection and Processing	24
1.6.4. Layout of the thesis	24
Chapter 2: Literature Review	27
2.1. Water Supply, Access and its Implication	27
2.2. Water Sources of Ethiopia	28
2.3. Surface Water Sources of Ethiopia	28
2.4. Groundwater Sources of Ethiopia	30
2.5. Water Service Provision Options	31
2.6. Water Accessibility and Indicators	31
2.7. Sources of Drinking Water.....	33
2.8. Water-related GTP	34
2.9. Water Coverage in Ethiopia.....	34
2.10. Availability of Adequate Water	35
2.11. Household Water Handling, Storage and Treatment	35
2.12. Personal Hygiene and Hand Washing Practices	37
2.13. Personal Hygiene	38
2.14. Hand Washing.....	38
2.15. Water Scarcity and its Causes and Coping Strategies.....	40
2.17. Causes of Water Scarcity	40
2.17.1. Socio-Economic Causes of Water Scarcity.....	41
2.17.1.1. Growth in Population.....	41
2.17.1.1. Coping Strategies Water Scarcity	42
2.16. Environmental Sanitation.....	42
2.17. Sanitary Inspection of Water Sources	46
2.18. Environmental Sanitation and Communicable Diseases.....	47
2.19. Needs of Water Supply and Sanitation	50
2.20. Water Security, Sanitation, and Poverty	52

2.21. Sanitation and Hygiene in Ethiopia: Status and Targets	58
2.22. The Sustainable Development Goals on Water and Sanitation.....	58
2.23. Access to Basic Sanitation	67
2.24. Health and Water Quality.....	68
2.25. Benefits of Improving Access to Water and Sanitation	69
2.26. Water Quality Parameters	71
2.26.1. Physical- Chemical Quality of Drinking Water	71
2.27.1.2. Hydrogen Ion Concentration (pH)	72
2.27. Bacteriological Water Quality Parameters.....	76
2.27.1. Coliform Bacteria.....	77
2.27.2. Faecal Coliforms (Thermo tolerant Bacteria)	77
2.28. Conventional Drinking Water Treatment.....	78
2.29.1. Coagulation for Drinking Water Treatment.....	79
2.29. <i>Moringa stenopetala</i> Seed Powder for Water Treatment.....	80
2.30. Water Supply and Sanitation Policy in Ethiopia.....	86
2.31. Sanitation Policy and Goals of Ethiopia	86
2.32.1. The Sanitation Vision for Ethiopia	86
2.32. Challenges in Water Supply and Sanitation.....	87
Chapter 3: The Research Design and Methods.....	92
3.1. Study Area and Period	92
3.2. Research Method.....	93
3.3. Research design.....	94
3.4. Sample Size Determination and Sampling Procedures	94
3.5. Study Variables	94
3.6. Data Quality Control.....	94
3.7. Sampling Procedures and Data Collection Methods.....	95
3.8. In-Depth Interview	96
3.9. Collection and Preparation of the Seeds of <i>Moringa Stenopetala</i>	96
3.10. Water Sample Collection and Analysis.....	98
3.11. Multivariable Logistic Regression	99
3.12. Ethical Considerations	100
3.13. Dissemination of Results	100
Chapter 4: Results.....	101
4.1. Sanitation-Hygiene Practices and childhood diarrhea among households in Robe and Ginnir town of Bale Zone Oromia Regional state South East Ethiopia.....	101

4.1.1. Socio-demographic characteristics of study subjects.....	101
4.1. 2. Water handling practices related to collection and transportation	102
4.1.3. Water handling practices related to storage and usage by households	104
4.1.4. Sanitary Conditions of the Six Protected Springs.....	105
4.1.5. Practices Related to Waste Management [Excreta] at Robe and Ginnir Towns.....	106
4.1.6. Personal Hygiene Practices	109
4.1.7. Factors Associated With the Presence of Childhood Diarrhea	110
4.1.8. Logistic Regression Result.....	113
4.2. Physico-chemical and Bacteriological Water Analysis of water samples from Ginnir and Robe towns.....	113
4.2.1. Physical Quality Parameter of Drinking Water in Robe and Ginnir Towns.....	114
4.2.2. Chemical Parameters of Sample Water from spring water Sources	116
4.2.3. Chemical Parameters Sample Water from Boreholes.....	117
4.2.4. Chemical Parameters of Sample Water from Reservoirs.....	118
4.2.5. Physico Chemical Quality Parameters Correlations	122
4.2.6. Evaluation of the treatment efficiency of <i>Moringa stenopetala</i> seed for selected parameters	125
Chapter 5: Discussion	128
5.1.Sanitation-Hygiene Practices and childhood diarrhea among households in Robe and Ginnir town of Bale Zone Oromia Regional state South East Ethiopia.....	128
5.2. Physicochemical quality of drinking water.....	132
5.3. <i>Moringa stenopetala</i> seed powder for water treatment.....	135
Chapter 6: Conclusion and Recommendations	136
Recommendations.....	138
References.....	140
Annexes	156
Questionnaire	156
Afaan Oromo version of questionnaire.....	165

|

Chapter 1: Introduction

1.1. Background

Access to safe water is a universal need and basic human right. It is known that water is our most precious resource, vital to our economy, our daily lives and for the health of our environment WHO, (2004A). The major sources of water are surface water bodies such as rivers and lakes, and underground aquifers (Ring, 2003). Water obtained from these diverse sources is not essentially pure since it contains dissolved inorganic and organic substances, living organisms (WHO, 2005A).

Water obtained from these sources has been used for drinking, washing, agriculture, and manufacturing. Since Water impacts nearly all areas of life, it is “everyone’s businesses” Kofi Anan, former UN Secretary-General, (UNESCO-WWAP, 2006).

As stated by WHO (2004A), Safe water is the entryway to health and health is the precondition for progress, social equity and human dignity. The Millennium Development Goal (MDG) stipulates that improvement in drinking water supply, sanitation and doubling the number of people with sustainable access to safe drinking water and basic sanitation through a pipe distribution system in urban centers and household water treatment and storage technologies in rural areas.

Report from WHO (2004A), revealed that, lack of water and sanitation hinder economic and social growth, and form a major barrier to poverty alleviation and certainly lead to environmental degradation WHO (2004A). Water shortages and increasing contamination, to a large extent, can result in social and political challenges (UNESCO-WWAP, 2006).

Since, protection of water supply from contamination is the first line of defense against disease; source protection is the best method of ensuring safe drinking water. Failure to give enough protection, poor site selection of water sources, and unhygienic practices of the consumers and deterioration of construction materials may contribute to the contamination of water sources and resulting water-borne diseases (Teferi, 2007).

As reported by UNICEF and WHO (2015) , sanitation remains a powerful indicator of human development in any community. The transition from unimproved to improved sanitation reduces overall child mortality. Improved sanitation also brings advantages for public health, livelihoods and dignity advantages that extend beyond households to entire communities.

Safe water and basic sanitation are basic needs of people's daily life and they have become urgent requirements for protection and improvement of people's health and living conditions, as well as for national economic development (Fewtrell, Colford. 2004).

According to (Prüss-Üstün *et al*, 2008), Water, sanitation, and quality hygienic practices have the possibility to prevent at least 9.1% of the global disease burden and 6.3% of all deaths.

1.2. Statement of Problem

Ensuring universal access to safe and affordable drinking water for all by 2030 requires we invest in adequate infrastructure, provide sanitation facilities and encourage hygiene at every level. Protecting and restoring water-related ecosystems such as forests, mountains, wetlands and rivers is essential if we are to mitigate water scarcity. More international cooperation is also needed to encourage water efficiency and support treatment technologies in developing countries. Water scarcity affects more than 40 percent of people around the world, an alarming figure that is projected to increase with the rise of global temperatures as a consequence of climate change. Although 2.1 billion people have gained access to improved water sanitation since 1990, dwindling supplies of safe drinking water is a major problem impacting every continent (FDRE Voluntary National Reviews on SDGs, 2017).

Targets for Goal 6

Goal 6 seeks to “ensure availability and sustainable management of water and sanitation for all”. It is a comprehensive goal addresses the entire water cycle, from access to use and efficiency, and the integrated management of water resources and water-related ecosystems.

Ethiopia has a vision of achieving 100% of basic Water and Sanitation and to meet expected target for safely managed WASH. To achieve these targets, Ethiopia will require more than US\$2 billion annually. Currently, the financing gap is estimated as 60 - 70% of SDG requirement. The ambition is highest for rural and urban water supply services where significant investment is required. In addition, access to water and sanitation services is significantly lower in poorer communities and among vulnerable groups (FDRE Voluntary National Reviews on SDGs, 2017).

Many developed regions have now achieved universal access to improved drinking water sources. However, coverage with improved drinking water sources varies widely in developing regions.

In sub-Saharan Africa, 24 percent of the population had access to safely managed drinking water, 34 percent of the population had access to basic drinking water services (UNICEF and WHO 2015).

The lowest levels of coverage of access to safe drinking water are found in the 48 countries designated as the least developed countries by the United Nations. Of these countries in which less than 50% of the population uses improved drinking water sources are all located in sub-Saharan Africa and Oceania. Although sub-Saharan Africa missed the MDG target, the population with access to improved drinking water source increased by 20 percentage points between 1990 and 2015, despite significant population growth (UNICEF and WHO 2015).

In 2015, it is estimated that 663 million people worldwide still use unimproved drinking water sources, including unprotected wells and springs and surface water. Of these populations, about 319 million (nearly half) people using unimproved drinking water sources live in sub-Saharan Africa (WHO, 2015; WHO/UNICEF; 2015).

According to World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) report of 2017, 844 million people who still lacked a basic drinking water service in 2015 either use improved sources with water collection times exceeding 30 minutes (limited services), use unprotected wells and springs (unimproved sources), or take water directly from surface water sources. One hundred

fifty nine million people still collected drinking water directly from surface water sources, 58% lived in sub-Saharan Africa.

More than 80 percent of the world's population lives in water scarce areas. This affects 3.4 billion people, almost all in developing countries. Nowadays, 1.6 billion people live in regions with absolute water scarcity. By 2025, two-thirds of the world's population may be affected by water stress conditions (UN, 2014).

In Ethiopia, According to EDHS 2016, 38.3% of the population has no access to improved drinking water sources uses water from unprotected dug wells, unprotected spring, a tanker truck and surface water. Among the people using these unimproved water sources, about 91 percent uses the water without treatment (EDHS, 2016).

During the MDG period, it is estimated that use of improved sanitation facilities rose from 54 percent to 68 percent globally. This indicates that the global MDG target of 77 percent has been missed by nine percentage and almost 700 million people.

Even though almost all developed countries have achieved universal access, but sanitation coverage varies widely in developing countries. Since 1990 the number of countries with less than 50 percent of the population using an improved sanitation facility has declined slightly, from 54 to 47, and countries with the lowest coverage are now concentrated in sub-Saharan Africa and Southern Asia.

Sub-Saharan Africa is one of the regions that remain furthest behind in terms of improved sanitation facilities. Between 1990 and 2015, the proportion of the population using an improved sanitation facility increased only from 24 percent to 30 percent (UN; 2015).

Of 2.4 billion people globally still using unimproved sanitation facilities, about 695 million peoples are found in sub-Saharan Africa. In 2015, it is estimated that 27 percent of the population uses unimproved sanitation facilities, and an estimated 23% practice open defecation.

The number of people practicing open defecation has actually increased in sub-Saharan Africa, and the region now accounts for a greater share of the global total than in 1990.

Ethiopia achieved the largest decrease in the proportion of the population practicing open defecation (from 92 percent in 1990 to 29 percent in 2015), a reduction over five

times greater than the regional average for the same period. Open defecation was practiced by 44.3 million Ethiopians in 1990 and 28.3 million in 2015 – an average reduction of over 4 percentage points per year over 25 years.

However, According to EDHS 2016, about 93% of Ethiopian households has no access to improved sanitation. About 54 percent of the populations are using unimproved toilet facilities and about 39% of populations are still practicing open defecation (EDHS, 2016). This Indicates that Access to improved sanitation is still a huge problem in Ethiopia.

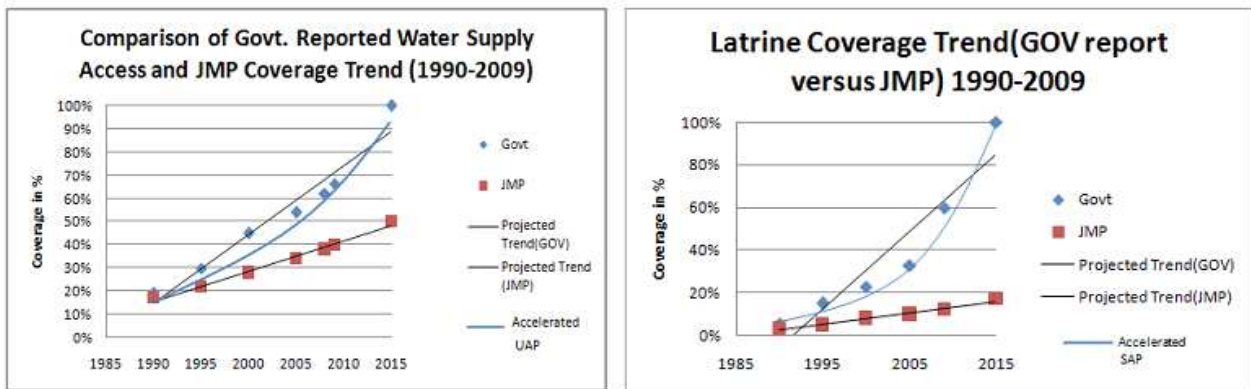


Figure 1: Trends in water supply and sanitation coverage in Ethiopia, comparing JMP with MoWE estimates and projections, from 1990 to 2015.

In the developing world, roughly 90% of sewage is discharged untreated into rivers, lakes and coastal areas (UNICEF, WHO, 2013), with widespread negative impacts on health (Corcoran et al., 2010).

Since open defecation is one of the main causes of diarrhea, which results in the death of more than 750,000 children under age of 5, every year and every 20 seconds a child dies as a result of poor sanitation. Eighty percent of diseases in developing countries are caused by unsafe water and poor sanitation, including inadequate sanitation facilities (UN, 2012).

Direct economic losses related to the treatment of water-related disease and loss of economic activity in sub-Saharan Africa total \$28.4 billion annually, about 5% of region's cumulative GDP.

According to the African Minister Counsel on Water Report of 2010, 12% of the population use improved toilets, 7% shared toilets, 21% traditional toilets, and 60 percent practice open defecation (8% and 71% rural) (AMCOW, 2010).

Figure 2: Trends in water supply and sanitation coverage in Ethiopia, comparing Joint Monitoring Program (JMP) with MoWE estimates and projections, from 1990 to 2015.

According to EDHS, (2014), proportion of Ethiopian population using an improved sanitation facility was about 4.5 % (17.5% for urban and 2.5% for rural households (33% in urban areas and 1 % in rural areas) use shared toilet facilities. The vast majority of households (89%), use non-improved toilet facilities (96% in rural areas and 53% in urban areas). The most common type of non-improved toilet facility is an open pit latrine or pit latrine without slabs, used by 57% of households in rural areas and 43% of households in urban areas (EDHS, 2014).

Despite the largest disparities in safe water and basic sanitation between urban and rural populations as well as regions of Ethiopia (Figure 4); problems with sanitation are intensified when there are inadequate drainage and waste removal. Where sanitation is poor, many people defecate in the open, or into plastic bags or paper thrown out with the household garbage. Excreta can accumulate rapidly in open areas and on garbage piles. Uncollected garbage is also frequently dumped in drainage ways, which quickly become clogged. When wastewater and stormwater cannot be easily drained, flooding spreads waste and excreta widely throughout the surrounding area (Bartlett 2003).

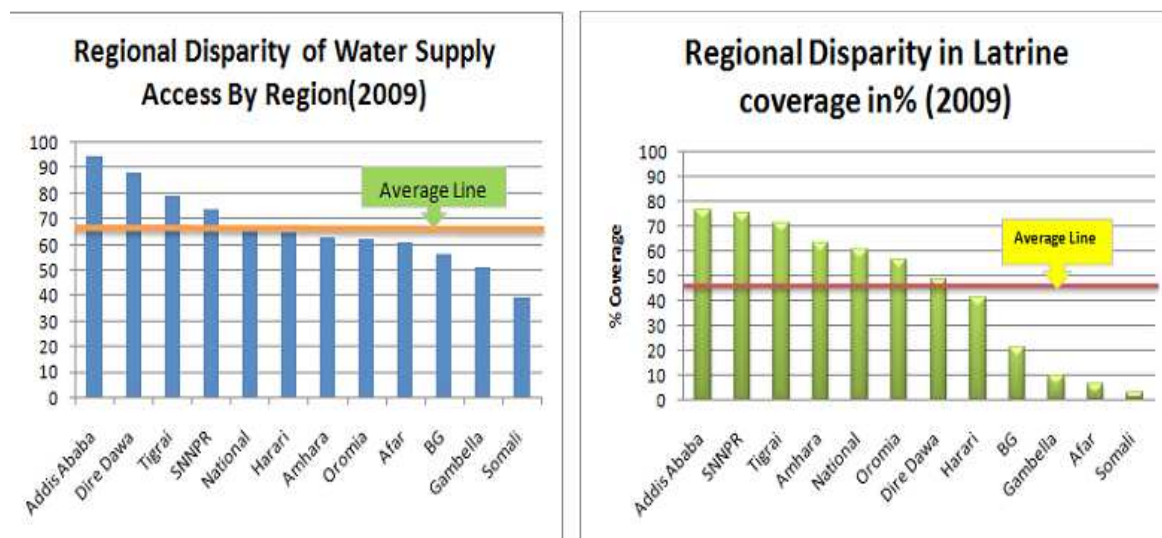


Figure 3 Regional disparity in water access and Latrine Coverage, 2009

1.3. Significance of the study

The study would serve to identify the problems and helps to distinguish the hygiene risk practices in households. In addition, the information gathered from the research will inform the activities of the environmental health program, to best achieve its goal of improved environmental health through better water and environmental sanitation services. The study also tries to evaluate the *Moringa stenopetala* seed in improving water quality.

It provides insight to policymakers, NGOs, community-based organizations and other stakeholders who are concerned with urban water supply and sanitation problems.

The study will also add to the literature of urban water supply and sanitation issues, which are currently the global challenges. It also serves as the baseline for further studies and to recommend Oromia Water Supply and Sanitation Bureau, Health Bureau and Local administrators to improve their efforts in supplying quality drinking water and increased access to the people.

1.4. Rationale of the study

Water resources, and the range of services they provide underpin poverty reduction, economic growth, and environmental sustainability. Access to water and sanitation facilities matters to every aspect of human dignity: from food and energy security to

human and environmental health, water contributes to improvements in social well-being and inclusive growth, affecting the livelihoods of billions. However, significant obstacles remain to realize the human right to safe drinking-water and sanitation. Today, hundreds of people are without access to an improved water source and billions of people globally use a source of drinking water that is faecally contaminated; in sub-Saharan Africa, women and girls spend 40 billion hours year collecting water (UN Water; 2013).

Currently, 2.5 billion people lack adequate sanitation facilities and over 1 billion practice open defecation, costing the world US\$260 billion annually. On current trends, without significant policy change and investment, around 1.4 billion people are projected to be without access to sanitation in 2050 (OECD, 2012).

The WHO estimates losses due to inadequate water and sanitation services in developing countries at US\$260 billion a year, 1.5 percent of global GDP – or up to 10 percent of GDP for some very poor countries (WHO, 2004).

Africa faces mounting challenges in providing enough safe water for its growing population. Sub-Saharan Africa fell short of the MDG target but still achieved a 20 percentage point increase in the use of improved sources of drinking water. In Ethiopia, though there was a remarkable change during MDG period, still the lack of adequate sanitation and access to safe drinking water is a major problem.

The current report also indicated that a majority of Ethiopian population has no access to safe drinking water and of these populations, all most all uses without treating the water. Hence, investigating the quality of drinking water, sanitation-hygiene practices and the potential of indigenous plant seed for water purification is important in order to minimize the impacts of these problems and to ensure access to adequate safe water supply and sanitation in the era of the Sustainable developmental goal.

The main reasons for selecting Robe and Ginnir Towns

According to officials of the health institutes in Robe and Ginnir Towns, water supply problem is critical and burning issue that requires urgent attention. The major health problems are internal parasite, thiphod, and acute fever illness. These are the most common water borne, and water related diseases linked to poor water quality supply

of the towns. The high prevalence of these water-associated diseases of these is an indication of the status of drinking water supply and personal hygiene.

The overall sanitation of the towns is poor. There is no system for collecting, transporting, and dumping waste in the towns. There is no liquid waste disposal system in the towns. The waste resulting from bathing and other domestic washing activities almost entirely thrown out into the streets. There is no specific site for liquid waste disposal.

Most of the excreta disposal facilities in Robe and Ginnir Town comprise pit latrines, which are frequently poorly constructed, offensive and over filled. According to the town's municipality, the majority of households use toilets in their own compound and the prevalence of open defecation is also significant and demands improvement.

1.5. Scope of the study

Inaccessibility of urban infrastructures like water and sanitation are the common problems in all over the world particularly in developing countries like Ethiopia. However, it is difficult to cover all the problems at once in all the areas. Hence, this study mainly focused on environmental sanitation practices, personal hygiene practices, and water quality analysis at Robe and Ginnir Towns of Bale Zone, Oromia Region, Southeast Ethiopia.

Moreover, sanitation is also a broad term, which includes solid waste management and liquid waste management. However, this study focused on latrine services and solid waste management at household level in the study area.

The data for this study is collected at household levels for the quantitative survey and water sample were collected from the sources (springs, borehole, and reservoirs) for physicochemical analysis and at household level for bacteriological analysis in the study area.

It also evaluates the *Moringa stenoplata* seed powder for removal of turbidity, nitrate and total hardness from the sample waters from the study area. The results from the study may not be generalized for the entire country or the regional state given the fact that the study was conducted in two urban setting of Oromia Regional state south East Ethiopia.

1.5.1. The Profile of Ethiopia

Ethiopia covers an area of approximately 1.14 million square kilometers and borders Djibouti and Somalia to the East and South East, Eritrea to the north, the Sudan to the West and South West, and Kenya to the south. The national capital is Addis Ababa. Ethiopia is a country of geographical contrasts from 116 meters below sea level in the Danakil depression to more than 4572 meters above sea level in the mountain regions. Ethiopia has various agro-ecological zones and three main climatic zones: Tropical rainy region, having an altitude of over 2500 meters above sea level; the Dry climatic region of hot low land lying up to 1500 meters above sea level; and Warm temperate wet region lying between 1500-2500 meters above sea level. Ethiopia is an ecologically diverse country, ranging from the deserts along the eastern border to the tropical forests in the south. Normally, the rainy season lasts from mid-June to mid-September (longer in the southern highlands) preceded by irregular showers from February or March; the rest of the year is generally dry (AACCSA, 2011).

According to the Encyclopedia of the Earth (2008), the Ethiopian economy is based on agriculture, which contributes 42 percent to GDP and more than 80 percent of exports, and engages 80 percent of the population. The major agricultural export crop is coffee, providing approximately 26 percent of Ethiopia's foreign currency.

Ethiopia is among countries having largest population in Africa with a growth rate of 2.7 percent. The country ranked 170 out of 177 countries in 2004 Human Development Index (HDI) (JMP, 2010). According to the census of 2007, the total population comprises 73.9 million of which 49.5 percent are female and 50.5 percent are male with a 2.6 annual growth rate during the period 1994-2007. This showed a decrease from the previous periods (CSA, 2007). Of these, 85 percent are estimated to live in rural areas.

The country has more than 77 ethnic groups with their own distinct languages, of which 56 ethnic groups are believed to be in the SNNPR. Most of the country people speak Semitic or Cushitic languages. The country has nine administrative regions and two self-governing administrations: Addis Ababa and Dire Dawa. These regions are Afar; Amhara; Binshangul Gumuz; Gambella Peoples; Harari People; Oromia; Somali; Tigray; and Southern Nations, Nationalities and Peoples Region (SNNPR)

(CSA, 2007). All these regions have their own administrative division, which is further classified into zones, districts (Woredas) and the smallest administrative unit (kebeles). This study was conducted on Robe and Ginnir the towns of the Oromia Regional State.

1.5.2. Profile of Oromia Region

The National, Regional State of Oromia is located within 3°24'20" –10°23'26"N latitudes and 34°07'37"-42°58'51"E longitudes, extending for about eight degrees (8°) west to east and for about seven degrees (7°) north to south or vice versa. According to Regional Statistics and Information Preparation and Dissemination Core Process, (2007), its total area is 363,399.8 km², accounting for more than 34.5 percent of the total area of the Democratic Republic of Ethiopia.

Agro-climatically, Oromia Regional State is characterized by semi-Desert/Bereha/Ho'aa, Tropical/Kolla/Gamoojjii, Subtropical/Woina Dega/Badda Daree, Temperate/Dega/Baddaa and Alpine (Cool) /Wurch/Dhaamotaa zones.

According to 2007 Population and Housing Census draft Result, the total population of Oromia National, Regional State (as of May 28) was 27,158,471 (female was 13,482,312). The Rural populations were 23,788,431 (female was 11,817,588), while urban population was 3,370,040 (female 1,664,724).

There are eight major drainage basins in the Regional State of Oromia. Regarding their surface coverage, Genale Basin covers about one-third of the total area of the Region, followed by Wabi Shebele and Abay Basins. Lakes of Oromiya can be categorized into the Rift Valley, Crater, Inland basin and Man-made. The Rift Valley sub-type is comprised of those lakes found in the Rift valley region. These lakes are also known as the Oromo Lakes (Ziway/Dembel, Abijata, Shala, Langano), Beseka, Abaya, Istifani, and Hawasa.

The Oromia National, Regional State is also known by having numerous hot springs like Sodere, Boku, Ambo and Weliso, Awash palm springs, and Gargadi (about 16 hot springs), Langano, Shala, and Guwanguwa (Wanlame) hot springs. These hot springs are well-known tourist attraction resources of the Region.

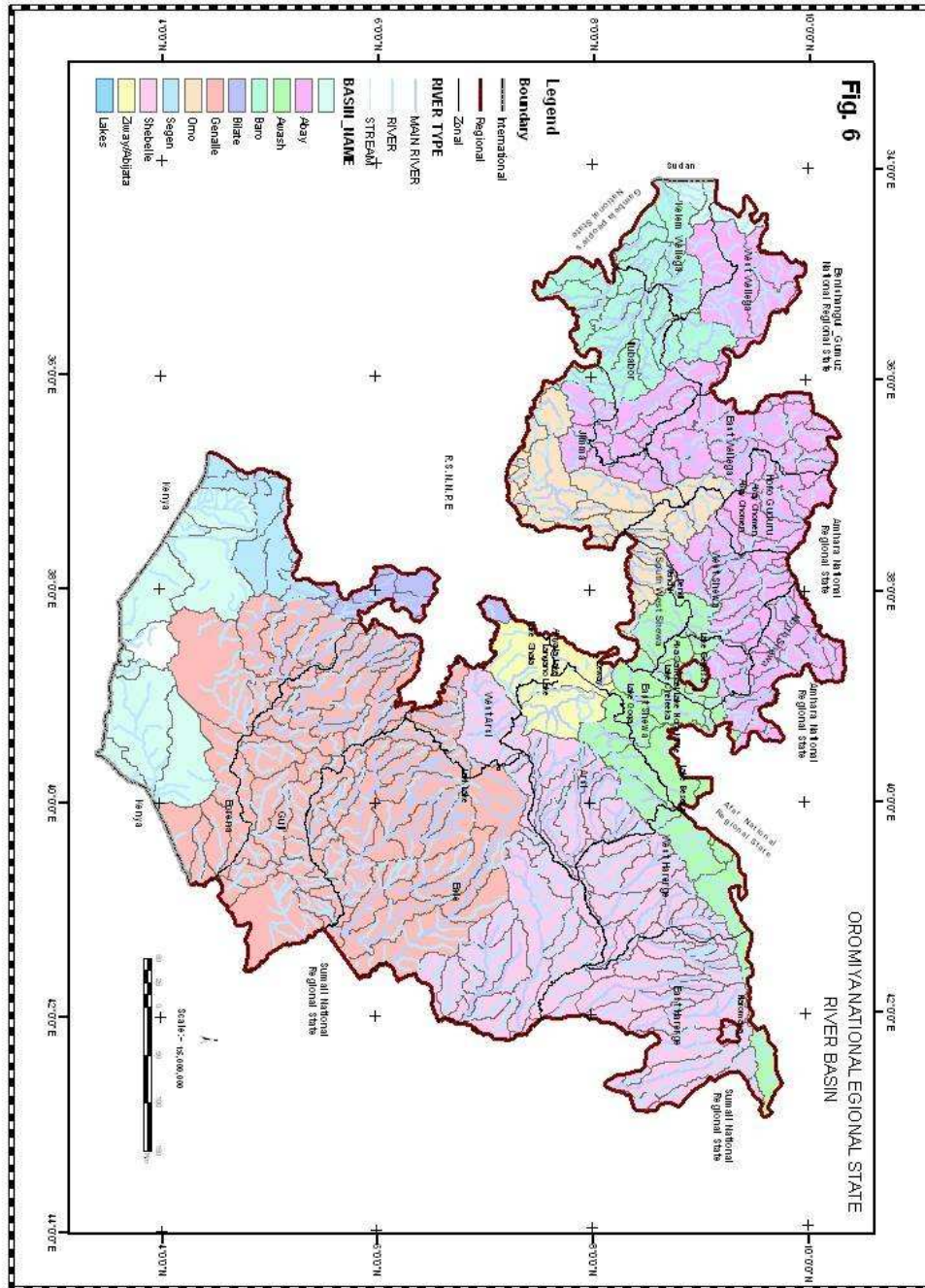


Figure 4 Oromia National Regional State River Basin

1.5.3. Profile of Bale Zone

Bale is one of the zones in the Oromia Region of Ethiopia and named for the former kingdom of Bale, which was in approximately the same area. Bale is bordered in the south by the Ganale Dorya River which separates it from Guji, on the west by the West Arsi Zone, on the north by Arsi, on the northeast by the Shebelle River which separates it from West Hararghe and East Hararghe, and on the east by the Somali Region.

The highest point in the Bale Zone, and also the highest point in Oromia, is Mount Batu (4,307 m), one of the Urgoma Mountains. Other notable peaks of the Urgoma include Mount Tullu Demtu, Mount Darkeena, and Mount Gaysay. Rivers include the Wabe and the Weyib; notable lakes include Garba Gurastsch and Hora Orgona. Points of interest in the Zone include Sheikh Hussein—named for the tomb of a Muslim saint—the Bale Mountains National Park, and the Sof Omar Caves. Towns and cities in Bale include Ginnir, Goba, and Robe.

1.5.4. Demography

Based on the 2007 Census conducted by the CSA, Bale Zone has a total population of 1,402,492, an increase of 15.16% over the 1994 census, of whom 713,517 are men and 688,975 women; with an area of 43,690.56 square kilometers, Bale has a population density of 32.10/km. While 166,758 or 26.20% are urban inhabitants, a further 44,610 or 3.18% are pastoralists.

A total of 297,081 households were counted in this Zone, which results in an average of 4.72 persons in a household, and 287,188 housing units. The three largest ethnic groups reported were the Oromo (91.2%), the Amhara (5.7%) and the Somali (1.44%); all other ethnic groups made up 1.66% of the population. Oromiffa was spoken as a first language by 90.46%, Amharic was spoken by 7.11% and Somali by 1.05%; the remaining 1.38% spoke all other primary languages reported.

The majority of the inhabitants, 81.83% were Muslims, while 16.94% of the population professed Ethiopian Orthodox Christianity and 1.04% were Protestant(CSA 2007).

The average annual temperature of Bale zone is 17.5°C. The maximum and minimum temperatures are 25°C and 10°C respectively. The mean annual rainfall of the zone is

875mm, whereas maximum annual rainfall 1200mm and minimum annual rainfall 550mm and recorded in the zone.

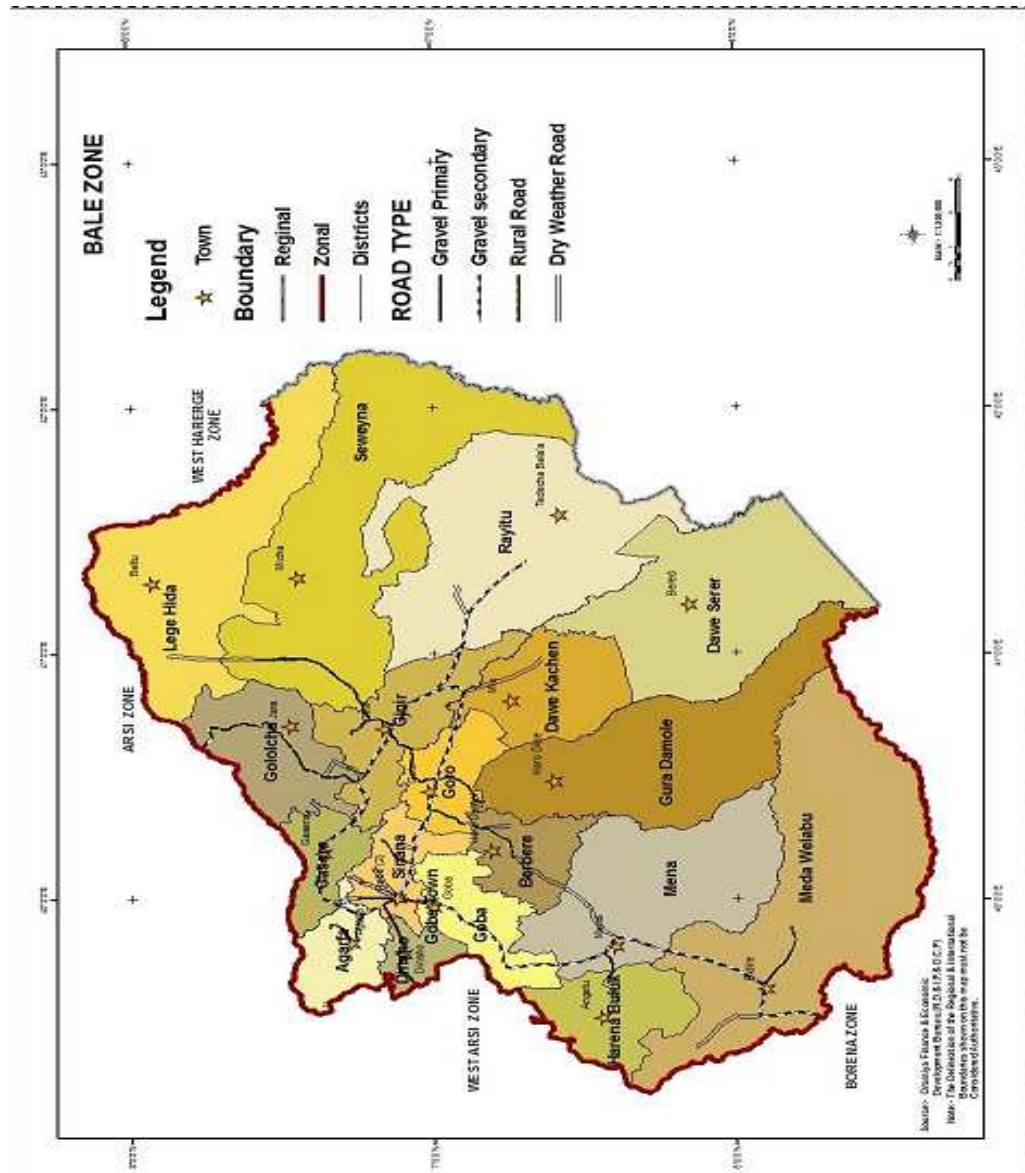


Figure 5 Map of Bale Zone

1.5.5. Drainage system of Bale Zone

Bale has numerous rivers, which are endowed in nature. It is estimated that there are about 55 perennial rivers, 18 seasonal rivers, and 70 springs, in the zone. Generally, Bale rivers are grouped into two major river basins namely; Genale river basin and Wabi Shabelle river basin. The Genale river basin is the largest basin whose catchment covers about 64.5% of the total area of the zone. This basin touches all the districts of the zone except Gololcha, Sawena and Laga Hidha. The basin is not

developed except for the Yadot mini-hydroelectric power station, which is the main source of electric supply for Mana town.

The Wabi Shabelle river basin catchment covers the remaining 35.5%, covering the north and northeastern part of the zone. It encompasses the whole districts of Gololecha, Sawena, Laga Hidha and parts of Gasera and Agarfa. The prominent river in this basin is Gololcha (Dhare).

1.5.6. Overview of Water Supply of Oromia Region and Bale Zone

Urban water supply coverage is the most important concern in water supply system and also a major issue in the achievement of MDGs. Hence, the Ethiopian Government has been working to attain water coverage as pre the MDGs.

Accordingly, the Ethiopian Government MDGs report of 2010 indicated that national water coverage is 91.5% and 65.85% in urban and rural areas respectively.

Parallel to the federal government, Oromia Water Resource Management Bureau has been working to reach the MDGs water coverage and the progress of urban potable water supply coverage in the region for the last five years is shown as follows:

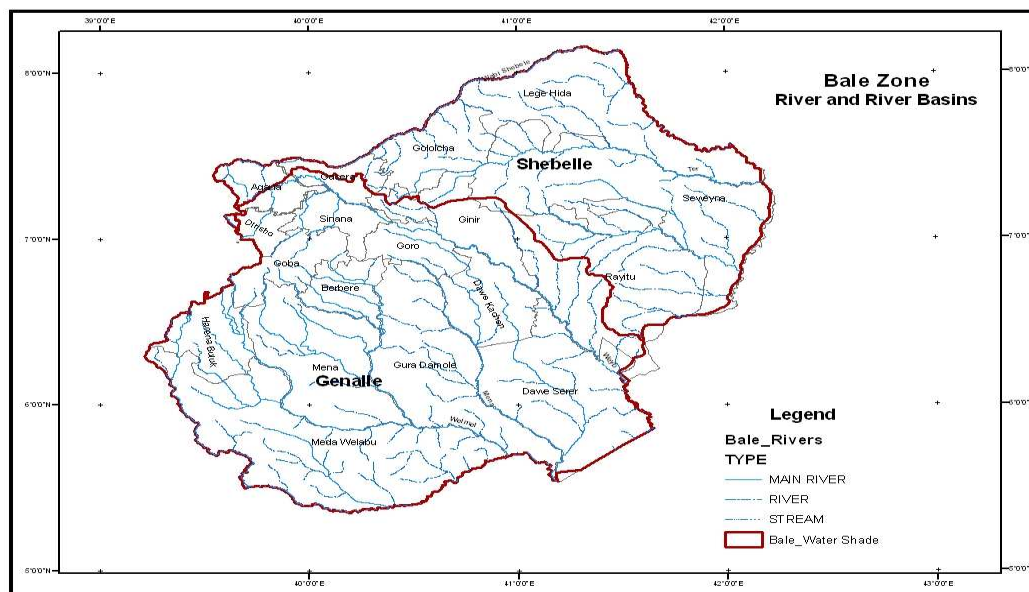


Figure 6 Bale Zone River and River basins

Table 1: Oromia Water Resource Management Bureau five years urban water coverage from 2006-2010.

Description	Years				
	2006	2007	2008	2009	2010
Total Urban Population	3562162	3370040	3552062	3687215	3856827
Urban Population served with potable water	2963185	3058196	3140148	3188520	3246838
Urban potable water coverage (%)	83.2	90.7	88.6	86.5	84.2

At present access to safe and consistent water supplies has focused government attention in Ethiopia. Accordingly, the national coverage rate for this service has gradually improved. Increased access to clean water is an integral part of Ethiopia's economic development and poverty reduction policy.

However, many water supply projects were built by different governmental and non-governmental organizations in the previous years; all of the implementing organizations were concerned with rural water supply projects and followed their own approaches based on their project interests. Some involved the local communities and needed contribution from the direct beneficiaries while others cover all the construction costs.

Like other developing countries, Ethiopia, Bale zone utilize more than one type of water source for drinking and other purposes. Sources of drinking water include private standpipe, public standpipe, dug well, protected and unprotected spring, boreholes, rivers, lakes, ponds, and rainwater.

Table 2: Principal sources of drinking water for Bale Zone, Ethiopia, 2010

Type	Functional	None functional	Total
Large & Medium Scale	10	0	10
On spot	47	6	53
Gravity	25	0	25
Motorized spring	4	0	4
Deep borehole	51	8	59
River intake	2	0	2
Machine drill	43	20	63
Hand dug well	37	19	56
Total	219	53	272

Table 3: Access to potable water in Different Woredas of Bale Zone, 2014

SUMMARY	Access to potable water in percentage		
BALE	URBAN	RURAL	TOTAL
Agrafa	100.00	65.96	73.34
Berbere	100.00	80.71	82.30
Dallo Manna	100.00	95.82	96.57
Dawe Qechan	100.01	78.96	80.65
Dawe Serer	100.01	84.05	85.89
Dinsho	100.00	51.07	60.13
Gasera	100.00	99.16	99.28
Ginnir	100.00	60.94	67.80
Goba	90.67		90.67
Goba (Rural)	100.00	73.86	76.02
Gololcha	57.26	92.11	89.88
Goro	95.48	50.02	57.59
Guradhamole	-	96.18	91.42
Harennna Buluq	100.00	81.73	82.96
Laga Hidha	99.99	40.71	42.85
Madda Welabu	100.00	73.79	75.56

Rayitu	100.00	64.52	68.34
Robe	104.60		104.60
Sinana	100.00	99.20	99.36
Soweyna	100.00	69.54	71.53
Total	97.72	76.36	80.24

1.5.7. Ten years trends in potable water coverage of Bale zone

Drinking water coverage is defined as the proportion of populations or households who have access to a safe drinking water source that ensures and/or limits the absence of pathogenic micro-organisms (Kumie, Ali, 2005).

Bale zone is one of the 18 second largest zones in the region. It has different topographies and climatic conditions. Both governmental and nongovernmental organizations are acting on a generation of water from different sources for the public. However, still, the potable water coverage is not proportional to the number of the population both in urban and rural settings. This study intended to analyze the ten years potable water beneficiaries in Bale zone.

Table 4: The ten years period water supply beneficiaries and access to potable water in Bale zone, Ethiopia, 2014

Year	Total population	Urban population	Rural population	Percent
1998	482,826	81.86	30.10	36.67
1999	507,363	82.11	31.46	38.13
2000	561,036	83.46	33.91	40.43
2001	611,612	83.94	36.30	42.62
2002	701, 546	87.73	41.13	48.09
2003	817, 194	87.60	48.62	54.64
2004	943,314	93.40	55.39	61.36
2005	1,152,211	96.09	67.64	72.73
2006	1,305,536	97.72	76.36	80.24
2007	1,382,817	97.75	79.33	82.74

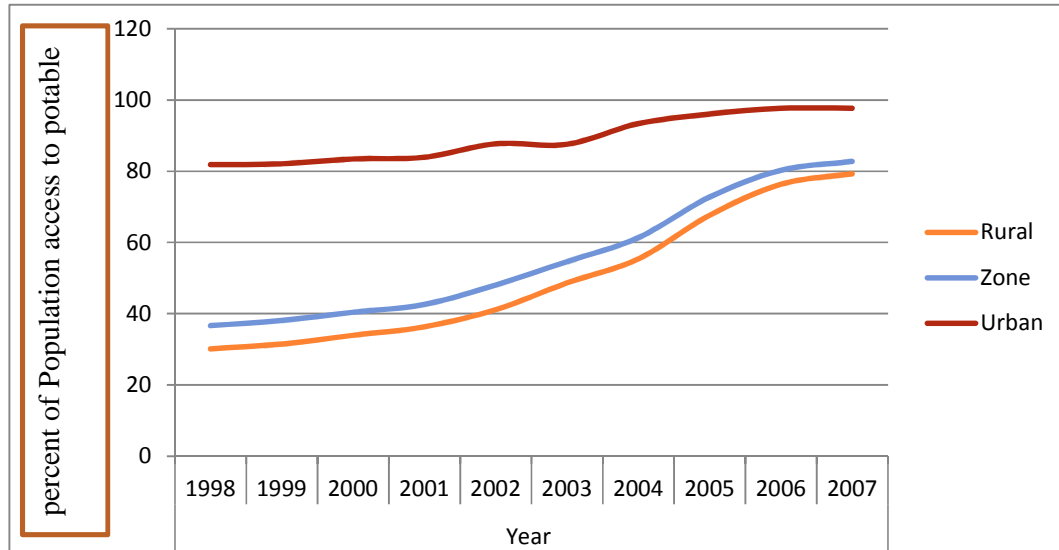


Figure 7 Ten years trend of potable water in percent, Bale zone, Ethiopia, 2014

1.5.8. Water sources of Robe Town

Formation of Robe Town Water Supply and Sewerage Service in 1937, water for the domestic use of Robe Town was obtained from Bamo River of Goba town area. Shaya River was pumped and water supplied to the town without adequate treatment but with only intermittent disinfection besides most of the township was not supplied. in 1997, water from Shaya River production of water for domestic use started to function.



Figure 8 : The taped springs of Robe Town water sources

1.5.9. Reservoirs and Distribution System of water in Robe town

In Robe Town, there are three springs called Oda, Werabu and Kaso Shekimira for water sources. There are three masonry reservoirs at the town with a capacity of 1500m³ each.

Town –Reservoir	Capacity in m ³	Raw water sources
Robe Reservoir 1	1500	Spring and Boreholes
Robe Reservoir 2	1500	Spring and Boreholes
Robe Reservoir 3	1500	Spring and Boreholes
Robe Reservoir 4	500	Spring



Figure 9: Madda Walabu University Reservoir



Figure 10 Photo of Borehole I of Robe Town, 2012



Figure 11 Photo of Reservoirs number 2 of Robe Town (Photo taken 2014)



Figure 11: Photo of Borehole 2 of Robe Town and Animals around the reservoir



Figure 12 :Water scarcity at study area (taken during survey period)

1.6. Aims and Objectives of the study

The aim of this study is to Investigate Drinking Water Quality and Sanitation-Hygiene Practices of Consumers and evaluates the potential of Indigenous Plant Seed as an alternative in the purification of drinking water at households in Oromia Regional state South East Ethiopia.

1.6.1. Specific objectives

- To investigate sanitation-hygiene practices of consumers in Robe and Ginnir town of Bale Zone Oromia Regional state South East Ethiopia
- To Investigate the Bacteriological and Physicochemical quality of drinking water of the Robe and Ginnir Towns of Bale Zone, Oromia Regional state South East Ethiopia
- To evaluate the efficiency of *Moringa stenopetala* seed in the reduction of turbidity, faecal coliform, hardness and nitrate levels from selected water sources.
- To Investigates the link between water and sanitation on under five diarrhea and identify the factors of Under five diarrhea in the study area

1.6.2. Research Questions

This study has the following research questions:

- What are the Sanitation Practices of Consumers in Robe and Ginnir town of Bale Zone Oromia Regional state, Southeast Ethiopia?
- What are the Physicochemical qualities (temperature, turbidity, pH, free residual chlorine, total dissolved solids, and electrical conductivity, nitrate, sulfate, Iron and phosphate contents) of drinking water of Robe and Ginnir towns of Bale Zone, Oromia Regional state south East Ethiopia?
- What is the Bacteriological drinking water quality of water samples using Total Coliform and Fecal Coliform indicators of Robe and Ginnir Towns of Bale Zone, Oromia Regional state south East Ethiopia?
- Can indigenous plant seeds be used as a feasible alternative for purification of drinking water in Bale Zone, Oromia Regional state south East Ethiopia?

1.6.3. Data Collection and Processing

This research work included household-based data collection on sanitation and hygiene practices of the two town communities.

Water sample collection from the two towns' water sources including Borehole, spring, Reservoirs, Distribution point and storage containers from selected Households.

The water quality analysis focuses on the Physicochemical qualities and Bacteriological drinking water quality.

1.6.4. Layout of the thesis

Chapters	Title of chapters	Overviews of chapters
1	Introduction	<ul style="list-style-type: none">• Background information• Statement of the problem• Significance of the study• Foundation for the study• The scope of the study.• Motivation of the study• Overview of study area• Research design and methods• Layout of the study
2	Literature review	<ul style="list-style-type: none">• Introduction to Ethiopia water sources• Water service provision options• Water accessibility and its indicators• Sources of drinking water• Water-related GTP of Ethiopia• Ethiopia water coverage from different perspectives• Water security, sanitation, and poverty• Sanitary inspection of water sources• Need of water supply and sanitation practices• Water supply and sanitation policy of Ethiopia• Health and Water quality

		<ul style="list-style-type: none"> • Water quality parameters • Conventional water treatment and <i>Moringa stenoplata</i> application for drinking water treatment
3	Research design and methods	<ul style="list-style-type: none"> • Study design • Research methods[sample size determination, sampling methods, data collection methods, data quality control and data analysis] • Water sample collection and analysis • Collection and preparation of <i>Moringa stenoplata</i> seed powder. • Ethical consideration • Dissemination plan
4	Result presentation	<ul style="list-style-type: none"> • Sociodemographic distribution of the study subjects • Water handling practices related to collection and transportation • Water handling practices related to storage and usage by households • Result on Sanitary conditions of the selected springs water sources • Water handling practices and under five diarrhea in the study area • Practices related to waste management [excreta] at the study area • Personal hygiene practices • Diarrhea and Waste management in the study area • Physicochemical parameters of water samples in the study area • Turbidity, Nitrate and hardness Removal efficiency of <i>Moringa stenoplata</i>
5.	Discussion	<ul style="list-style-type: none"> • Water handling practices related to collection and transportation and storage at Household level • Result on Sanitary conditions of the selected springs

		<p>water sources</p> <ul style="list-style-type: none"> • Practices related to waste management [excreta] at the study area • Physicochemical parameters of water samples in the study area • Turbidity, Nitrate and hardness Removal efficiency of <i>Moringa stenoplata</i>
6.	Conclusion and recommendations	<ul style="list-style-type: none"> • Water handling practices related to collection and transportation • Water handling practices related to storage and usage by households • Water handling practices and under five diarrhea in the study area • Practices related to waste management [excreta] at the study area • Personal hygiene practices • Physicochemical parameters of water samples in the study area • Turbidity, Nitrate and hardness Removal efficiency of <i>Moringa stenoplata</i>

Chapter 2: Literature Review

2.1. Water Supply, Access and its Implication

As stated by WHO & UNICEF (2013), the Joint Monitoring Programme for Water Supply and Sanitation defined safe drinking water as "water with microbial, chemical and physical characteristics that meets WHO guidelines or national standards on drinking water quality." The guidelines include an assessment of the health risks presented by the various microbial, chemical, radiological and physical constituents that may be present in drinking water.

According to WHO/UNICEF (2012), Lack of potable water is a vast problem and a major cause of death and disease in the world. 783 million people worldwide are without improved drinking water, and the World Health Organization estimates that lack of proper drinking water causes 1.6 million deaths each year from diarrheal and parasitic diseases. In many parts of the world river water which can be highly turbid is used for drinking purposes. This turbidity is conventionally removed by treating the water with expensive chemicals; many countries must import expensive chemicals to clarify the water, limiting the amount they can afford to produce these imported chemicals with a great expense.

Purifying water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi, as well as reducing the amount of a range of dissolved and particulate material derived from the surfaces that come from runoff due to rain. Chemical coagulants like Aluminum sulfate (alum), FeCl_2 are used in municipal drinking water treatment plant for purification process. This excess use of amount of chemical coagulants can affect human health e.g. Aluminum has also been indicated to be a causative agent in neurological diseases such as pre-se-nile dementia.

Studies by Fewtrell et al., (2005); and Waddington et al. (2009) have reported the significant positive effect of clean water on reducing the risk of childhood diarrhea. Moreover, improved water quality has been shown to lower the health risks related to bilharzia, trachoma, intestinal helminths and other water-related diseases. In addition, improved water quality is likely to reduce the burden of disease related to other major

health issues by reducing the average stress level for the immune system, and thus strengthening the resistance to respond to new infections.

According to the study conducted on the impact of water and sanitation on children nutritional status in a cohort of Peruvian children revealed that nutritional status is related to the quality of water and sanitation interventions and highlights the need to improve sanitation in developing countries. More consistent water sources reduce the risk of contaminated water, decrease the diarrheal incidence, and helps for better growth in children.

2.2. Water Sources of Ethiopia

Ethiopia receives an average annual rainfall of around 1,200 mm. Its distribution is highly uneven, with 80 to 90 percent of surface water potential occurring in basins in the western and southwestern parts of the country. The central and eastern parts of the country have less than 20 percent of the total surface water. Some areas of the southeastern part of the country receive less than 200 mm of rainfall per year. The rainfall, when it does arrive, can often overwhelm local drainages, resulting in flooding that affects both livelihood and lives, limited infrastructure for water storage and watersheds protection further exacerbate these problems (Nuru, 2012).

2.3. Surface Water Sources of Ethiopia

As reported by Awulachew *et al.* (2007), Ethiopia has eight river basins, one lake basin, and three dry basins that do not support any perennial rivers (Figure 1.1). These basins can be categorized as follows: river basins (Tekeze, Abbay, Baro–Akobo, Omo–Gibe, Genale Dawa, Wabi Shebele, Awash, Danakil); Lake Basin (Rift Valley Lakes); dry basins (Mereb, Ayisha, Ogaden). With the exception of the Awash River and Rift Valley Lakes Basins, these are transboundary.

Nuru (2012) reported that the Abbay, Baro–Akobo, Mereb, and Tekeze Rivers flow into Sudan, cross into Egypt and drain to the Mediterranean forming part of the Nile Basin system. The Omo–Gibe River is the major tributary to Lake Turkana, which lies between Ethiopia and Kenya. The Omo–Gibe enters the Ethiopian part of Lake Turkana, making the lake an international water basin. The Genale Dawa and Wabi Shebele Rivers flow into Somalia before disappearing into the sand near the Indian

Ocean. The remaining three basins are also trans-boundary, although they do not generate any trans-boundary run-off.

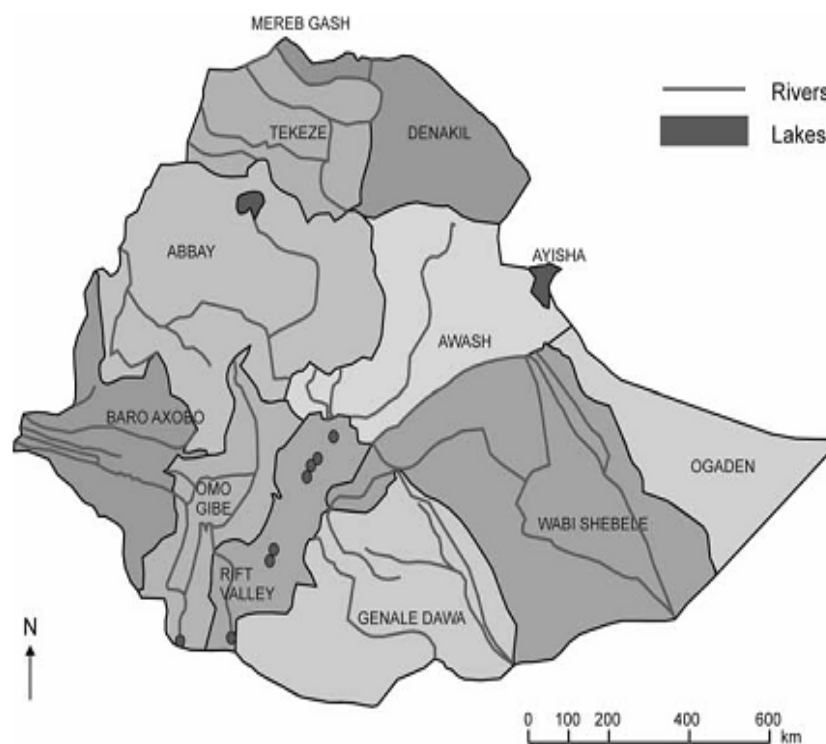


Figure 13: Schematic map of Ethiopia's river basins. *Source: Nuru, 2012.*

Table 5: Distributions of River Basin in Ethiopia

<i>S/N</i>	<i>River basin</i>	<i>Catchment area</i>	<i>Annual runoff(billion m³)</i>	<i>Specific discharge(1/s/Km2)*</i>
	Abbay	199812	52.6	7.8
	Awash	112 700	4.6	1.4
	Baro-Akobo	74100	23.6	9.7
	Genale-Dawa	171050	5.80	1.2
	Mereb	5700	0.26	3.2
	Omo-Gibe	78200	17.90	6.7
	Rifty Valley	52 740	5.60	3.4
	Tekeze	89 000	7.63	3.2
	Wabe Shebele	200 214	3.15	0.5

Source: Ministry of Water Resource (MWR), 2002

2.4. Groundwater Sources of Ethiopia

Groundwater is used as the most important source of drinking water supply in the world. In both developed and developing countries, the use of groundwater has been increased among the populations in rural areas, as well as in the rapidly expanding urban areas. As a result of the inadequate availability of surface water and its continuous deterioration in quality, the dependence on groundwater will increase even further during the next decades.

Groundwater has many advantages over surface water. In its natural state, it is free from pathogenic microorganisms and has lower concentrations of organic matter. The occurrence of groundwater in Ethiopia is influenced by the country's geology, geomorphology, tectonics, and climate. These factors influence the availability, storage, quality, and accessibility of groundwater in different parts of the country.

In some lowland areas of the country (e.g. Somali Region) groundwater is only available at depth while, in other areas, its quality poses a risk to human health (e.g. from high fluoride concentrations in the Rift Valley). However, groundwater is of potable quality and can be developed in a cost-effective manner to meet dispersed demands across much of the country. Hence groundwater, accessed through wells, boreholes or springs, probably provides over 90 percent of improved rural water supply and underpins efforts to achieve the drinking water targets set out in the UAP. About 8.4% of the urban and 56.8% of the rural population of the Ethiopia utilize groundwater sources for potable water consumption (FMOH, 2006).

At the national level, a water supply and sanitation master plan covering a development scenario up to 2025 envisage the construction of more than 60,000 schemes, the majority of which include hand dug wells and springs development. Groundwater abstraction for consumption purposes will therefore continue to rise due to increased population and the associated demand. However, the geology of the country is not favorable for the efficient use of groundwater resources due to excessive extraction costs (DHV, 2003).

The accessibility of water with respect to population distribution and settlement also presents challenges. Approximately 85 percent of Ethiopia's surface water is found in the western basins, but only 40 percent of the population lives in these areas. The bulk

of the population is concentrated in the highlands because of favorable climatic conditions, but water storage in these areas is lower. The lowlands have greater surface water flows, groundwater storage, and land availability, but remain sparsely populated.

2.5. Water Service Provision Options

According to UN-HABITAT (2006), Water service provision options are standpipes, yard, and house connections. In household connection, water service provision, the water pipe is connected within house plumbing to one or more taps (e.g. in the kitchen and bathroom) or tap placed in the yard or plot outside the house. Public tap or standpipe is a public water point from which people can collect water. Many low-income households that are unable to afford a household connection are relying on public water points.

2.6. Water Accessibility and Indicators

According to UN-HABITAT, (2003), Access to safe water is the distribution of the population with reasonable access to a sufficient amount of safe water. Safe water includes treated surface water and untreated but uncontaminated water such as from springs sanitary wells and boreholes. In urban areas, the water source may be a public fountain or a standpipe not more than 200 meters away from households. A sufficient amount of water is that which is needed to satisfy metabolic, hygienic and domestic requirements usually about, 20 liters of safe water per person per day. This minimum quantity, however, varies depending on whether it's an urban location or rural and whether warm or hot climate. Accessibility must be seen within the situation of the ease with which people can get the services of a facility and function. Accessibility increases with decreasing constraint both physical and social. Water accessibility is the balance between the demand for and the supply of consumer services over a geographic space and narrowing or bridging the gap between geographic spaces is all significance of transport.

As stated by WHO (2004), to measure water accessibility there are basic indicators. These indicators show four main levels of water accessibility that includes optimal access, intermediate access, basic access and no access. These are indicative of the level of water availability, which is a measure of the quantity available for use.

Basically, they reflect the extent to which accessibility challenges such as time, distance and affordability are formidable or otherwise.

Table 6: WHO Water accessibility Indicators

Travel distances to collect water	WHO standard	Average time spent to collect water	WHO Standard
Water supply through taps continuously	(Optimal access)	Water supplied through multiple taps Continuously	Optimal access
< 100m	Water supplied through multiple taps continuously	Within 5 minute	Intermediate Access
101-200m	Between 100 and 1000m	5-30 minutes	Basic access
201-500m			
5001-1000m	Basic access	30 minute-2hours	No access
		2-4hours	
1.2-2km(1.5km)	More than 1000m (No access)	>4 hours	No access
>2km(3km)			

Source: WHO, (2004)

According to Public Health Protection, (2000), affordability of water has a considerable pressure on the use of water and selection of water sources. Households with the lowest levels of access to safe water supply frequently pay more for their water than households connected to a piped water system. The high cost of water may force households to use small quantities of water and alternative sources of poorer quality that represent a greater risk too.

According to a report by Alaci and Alehegn (2009), private access to tap water is the cheapest for the consumer. Dependence on a shared standpipe increases prices almost four times. Private water delivery through tanker service (or sachet or bottled water) is the most expensive and tanker water delivery costs many times the tap water price. Thus, the consumers paying the most for water are the ones with the lowest income.

According to WHO, (2004), time and distance traveled to fetch water are also key indicators of water accessibility. For most communities of Africa, long-distance travel to fetch water is common. Hence, they spend much time and money. If households travel more than 200 meters far away from the house in urban areas, there is no access for drinking water. Distance travel to fetch water is also one of the indicators of water accessibility. WHO standards in relation to time, more than 30 minutes no access 5 minutes - 30 minutes basic access and within 5 minutes intermediate access.

2.7. Sources of Drinking Water

As stated by UNICEF, (2006), sources of drinking water can be Improved and Unimproved. Population using improved sources of drinking water are those with any of the following types of water supply: piped water (into dwelling yard or plot), public tap or standpipe, tube well or borehole, protected well, protected spring and rainwater collection while unimproved sources are unprotected dug well, unprotected spring, surface water (river, dam, lake, pond, stream, canal, irrigation channel), vendor-provided water (cart with small tank or drum, tanker truck), bottled water, tanker truck-provided water.

Table 7: Types of sources of drinking water and sanitation

Water supply		Sanitation	
<i>Improved</i>	<i>Unimproved</i>	<i>Improved</i>	<i>Unimproved</i>
Household connection	Unprotected well	Connection to a public sewer	Service or bucket latrines
Public standpipe	Unprotected spring	Connection to septic system	Public latrines
Boreholes	Vendor-provided water	Pour-flush latrine	Latrine with an open pit
Protected dug well	Unprotected dug well	Simple pit latrine	-
Protected spring water	Tanker-truck provided	Ventilated improved pit latrine	

Source: JMP, 2006

2.8. Water-related GTP

Improved access to water supply and sanitation is a key indicator of social development and forms a major part of most countries' poverty reduction strategies. In Ethiopia, the overarching strategy is the GTP, which sets out a national development path for the period 2010/11 to 2014/15. The GTP recognizes the importance of water provision and the development of relevant institutions to manage water service delivery at appropriate administrative levels (MoFED, 2010).

According to MoFED, (2010), the GTP states that the key objective for the water sector from 2010–15 is 'to develop and utilize water for different social and economic priorities in a sustainable and equitable way, to increase the water supply coverage and to develop irrigation schemes so as to ensure food security, to supply raw materials for agro-industries and to increase foreign currency earnings'.

Table 8: Water-related targets in the Growth and Transformation Plan

	Baseline 2009/10	Target 2014/15
<i>Potable water Coverage (%)</i>	68.5	98.5
Urban potable water coverage(source within 0.5Km)	91.5	100
Rural potable water coverage(source within 1.5Km)	65.8	98
Reduce nonfunctional rural water supply schemes (%)	20	10
Developed irrigable land (%)	2.5	15.6
Power generating Capacity(MW)	2,000	10,000

Sources: MoWE, 2011a; WHO and UNICEF, 2012

2.9. Water Coverage in Ethiopia

The national and international reported figure of water supply coverage in Ethiopia indicates a great variation. This difference might be due to the difference in data collection methods used by Governmental agencies and other international NGOs. The JMP has based its reporting on user information gathered from household surveys undertaken by national statistical agencies, rather than data for service provision gathered by government ministries.

Table 9: Rural and urban water supply coverage for Ethiopia, 2010

Area/residence	<i>MoWE</i> water access coverage (%)	<i>JMP</i> use of improved water facilities (%)
Rural	65.8	34
Urban	91.5	97
Total	68.5	44

Sources: *MoWE, 2011a; WHO and UNICEF, 2012*

2.10. Availability of Adequate Water

The WHO/UNICEF Joint Monitoring Programme (JMP), which produces the Global Assessment of Water Supply and Sanitation data, describe reasonable access as being 'the availability of at least 20 liters per person per day from a source within one kilometer of the users dwelling' (Howard ,2003). Although 20 liters per person per day is the WHO/UNICEF standard for household water consumption, it has been estimated that at least 30–40 liters a day are needed per person if drinking, cooking; laundry and basic hygiene are all taken into account (Bartlett, 2003).

2.11. Household Water Handling, Storage and Treatment

Access to safe water alone does not reduce diarrheal diseases significantly. Even if the source is safe water may become contaminated with faecal matter, during collection, transportation, storage and drawing in the home (Thomas F. Clasen and Sandy Cairncross, 2004).

As reported by UNICEF, (2008), protected water sources never guarantee that water used for drinking and cooking in the home is safe. Household water storage – a practice common in developing countries, contributes to drinking-water contamination. Water stored in homes is often faecally contaminated at levels far above the contamination level at the source. Studies show that water stored in homes routinely have faecal coliform levels hundreds of times higher than is present in the source – some studies have documented thousand-fold increases in faecal Coliforms.

A report from UNICEF (2008), revealed that many types of vessels are used to store and transport water in developing countries, including traditional clay pots, metal containers, mortar jars, plastic and metal buckets, jerry cans, beverage bottles, barrels, and plastic vessels or tanks.

According to WHO (2003), key factors in the provision of safe household water include the conditions and practices of water collection, storage and the choice of water collection and storage containers or vessels. Numerous studies have documented inadequate storage conditions and vulnerable water storage containers as factors contributing to increased microbial contamination and decreased microbial quality compared to either source waters or water stored in improved vessels.

The result obtained from the study done in Northeast Thailand suggested that there was a far greater risk of ingestion faecal coliform bacteria resulting from the cross contaminations occurring within the household than from the faecal pollution of drinking water sources. Mean coliform counts were substantially higher in household water containers than in water sources. In their study on waterborne transmission of cholera in Trujillo, Peru, Swerdlow et al tested the water quality variation at the source and later in the household (i.e. Stored water). The result showed that the mean coliform counts were 1 and 20 fecal coliform /100 ml of the well water and stored water respectively (Swerdlow, et al. 1992).

All water containers should be clean, especially inside. It is always best to clean the insides of storage containers with either detergent or chlorine. The top of the water container should be covered to stop dust and other contaminants falling into the drinking water. It is best for water to be poured from the container to prevent contact with dirty fingers and hands. When scoops are used to take water out of the storage container they should be clean and kept in the water storage jar. They should never be placed on the floor (Howard 2002).

A study conducted in rural Bangladesh showed water stored for longer period increase vibrio cholera rate by 10 folds (Shears, 1995). A similar study in Venda, South Africa indicated water stored in plastic vessels have higher levels of coliform over time (Verweij, and Van Egmond, 1991). Another study in the same area of rural Bangladesh showed water stored in traditional pots increase faecal coliform levels and multiple antibiotic resistance flora than other storage containers (Shears, 1995).

Similarly in Calcutta, India water storage vessels which have wide mouth increase cholera infection by 4 folds. Unrestricted and unhygienic water collection activities, soiled hands and unclean water collection vessels were a potential contributor to the contamination of drinking water in Lesotho and elsewhere. The highest level of household water contamination is found in stored water since stored water becomes contaminated when unclean objects touch it over dipping (Kravitz, 1999).

A study conducted in South Wollo showed among the total of 192 study households 141(73.4%) rinsed their collection containers. In addition, 178(92.7%) had cover for their storage vessels and 138(72%) drew water from the storage container by dipping (Tiku, Legesse and Kebede, 2003).

In Garamuleta district Eastern Ethiopia, only 60.0% of the studied families stored their water in covered containers. In another study conducted in Kidame Gebeya, it was found out that 58.0% of the households kept their water in clean and covered containers (Kitaw, 1980).

Similarly, a study conducted in Jimma town showed 70.4% of the studied population taking water from the storage container by dipping rather than pouring, out of these, 52.2% use cup without handle (Teklu and Kebede, 1998).

2.12. Personal Hygiene and Hand Washing Practices

Hygiene is the practice of keeping one's self and one's surroundings clean, especially to avoid illness and the spread of infection. The focus is mainly on personal hygiene that looks at the cleanliness of the hair, body, hands, fingers, feet, and clothing (Ministry of Health 2011b).

According to IFRC/RCS, (2007), the majority of people usually do not practice hygiene for health reasons, but rather for other motivations like a dislike of dirt, aesthetic preference for cleanliness, a desire to protect their children and themselves from dangerous, external influences, or, (most commonly of all), considerations of status, self-respect and social standing.

2.13. Personal Hygiene

Personal hygiene is defined as a condition promoting sanitary practices to the self. Generally, the practice of personal hygiene is employed to prevent or minimize the incidence and spread of communicable diseases (Ministry of Health 2011). Regular bathing/showering, hand washing, and good general personal hygiene can reduce the risks of self-infection (Bloomfield & Nath 2006).

According to MoH, (2011), the primary duty of personal hygiene is to find water, soap and other cleaning materials. Taking a bath or a shower using body soap at least weekly is very important to ensuring our body stays clean.

They also prevent hygiene-related diseases such as scabies, ringworm, trachoma, conjunctivitis and louse-borne typhus.

Bathing with soap is an important means of preventing the transmission of trachoma, an illness that can cause blindness and other eyesight problems. Children's faces, in particular, should be washed regularly and thoroughly (Howard, 2002).

2.14. Hand Washing

According to World Bank report, (2005), human excreta are the main source of diarrheal pathogens. They are also the source of shigellosis, typhoid, cholera, all other common endemic gastro-enteric infections, and some respiratory infections. These pathogens are passed from an infected host to a new one via various route all emanate from feces. Sanitation and hand washing after fecal contact can prevent faecal pathogens from reaching the domestic environment in the first place.

As reported by World Bank, (2005), hand washing is one of the most effective means of preventing diarrheal diseases, along with safe stool disposal and safe and adequate household water supply. Hand washing with soap, particularly after contact with feces (post-defecation and after handling a child's stool), can reduce diarrheal incidence by 42-47%.

According to IFRC/RCS (2007), hand washing activities are strongly influenced by the presence or absence of a suitable source of water and soap. Proper hand washing behavior includes hand washing supplies, hand washing at critical times and hand washing technique.

As reported by World Bank, (2005), hand washing with any soap and water adequately removes microbe-containing dirt from hands. For this hand have to be covered with soap and then rinsed off.

According to Pickering and Davis (2012), Improved household water quality is expected to reduce the risk of childhood diarrhea by acting as a barrier to disease-causing pathogens. The traveling and waiting time used for collecting water determines the amount of water collected by a given household and reduces the time available for child care and other activities. A recent empirical study has shown that the time spent on fetching water from distant sources for domestic use significantly affects child health. Insufficient water may also limit good hygiene practices, such as washing hands regularly at critical times. Overall, water collection time is assumed to be positively correlated with childhood diarrhea incidence. The practice of hand washing with soap, which is a defensive mechanism to improve household health and therefore expected to be negatively correlated with diarrhea incidence.

A typical description of the recommended hand washing process is: wet the hands, rub both hands thoroughly with an agent (soap, ash or mud) for 20 seconds and rinse completely and (air) dry (Shordt, 2006).

As reported by Environmental Health Project, (2004), critical moments that WHO lists as the instances for maximum effect on diarrheal disease reduction include the following: after defecation, after handling children's faeces or cleaning a child's bottom, before preparing food, before feeding a child and before eating.

To encourage hand washing to become part of the daily routine, suitable facilities must be located near to places such as latrines and kitchens, where they are needed. The facilities should include a tap and a sink as well as soap or locally available detergents (Howard, 2002).

According to World Bank 2005, global rates of hand washing with soap are very low due to lack of soap that presents in the majority of households worldwide, but it is commonly used for other purposes than hand washing. The cost of soap also limits hand washing by the family in many settings (Curtis et al 2000). Personal hygiene and hand washing practices can prevent or minimize the incidence and spread of communicable diseases, for this understanding the way the diseases transmitted is very crucial to take an intervention.

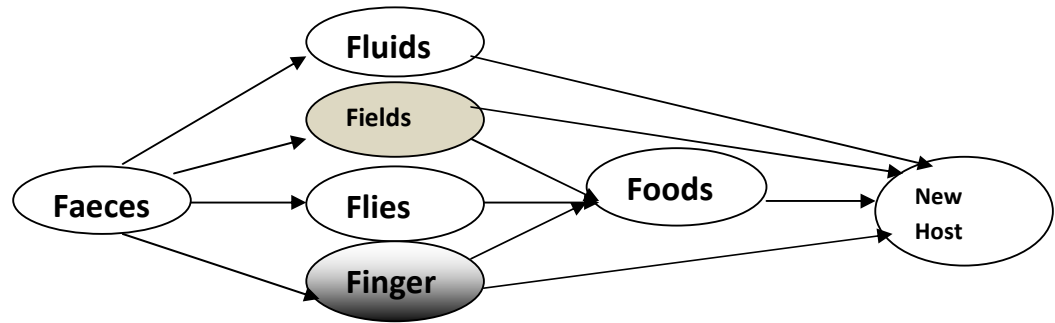


Figure 14: **The F-diagram for fecal-oral disease transmission (Curtis, Cairncross)**

2.15. Water Scarcity and its Causes and Coping Strategies.

According to (MoWR, 2002), Water scarcity is a relative concept. It can occur at any level of supply and demand. Water can be scarce in supply, in access and in usability or quality. Different kinds of literature defined water scarcity of a region or a country using different methods. Water scarcity is an imbalance of supply and demand under prevailing institutional management and/or prices *i.e.* an excess of demand over available supply. water scarcity can be demand driven or supply driven. Demand-induced scarcity occurred when the need for water is higher with increasing population. Supply-induced scarcity resulted when rivers running dry, lowered the water table and polluted groundwater as well as surface water sources.

2.17. Causes of Water Scarcity

Climate Change: The water cycle is an integrated and dynamic component of the earth's geophysical system that affects and is affected by climatic conditions. Change in temperature affects evaporation and transpiration rates, cloud characteristics, soil moisture, snow flow and snow melt. Similarly, change in precipitation affects the timing and magnitude of flood and drought. In such way, Climate change is perhaps the most common and unpredictable problem that farmers in the dry land have to face year by year. Owing to this, one of the most challenging current and future natural resources, especially in the arid and semi-arid region is, therefore, water scarcity. In the case of Ethiopia, climate change is often manifested as a decrease and /or seasonal shift in rainfall or as a change in the distribution of the rainfall pattern. Water availability is changing fast in Ethiopia. Some areas that used to be covered by water

have become grazing areas due to climate change. The water level has been seriously depleted and rivers are now drying up because of meteorological drought thereby affecting the economy (MoWR, 2002).

Drought: In general term, drought can be viewed as a natural shortfall of precipitation and water resources to a level that does not meet the use established for normal conditions. Drought is, therefore, an abnormal shortage of water or moisture and hence the problems of drought management are actually a problem of water management. The effect of drought, however, spells beyond water resources as it could affect society and its living condition as well as the environment (MoWR, 2002). Drought is the most important adverse impact of climate change in Ethiopia. Because of extreme natural resource degradation and exploitation, change in rainfall amount as well as patterns and high population pressure, drought has now become more frequent and severe in our country. The distribution of rainfall pattern has become extremely erratic and unpredictable with the frequent seasonal shift. As the result, drought has now started to affect even those areas that used to receive high rainfall (MoWR, 2002). Even though Ethiopia gets plenty of annual rainfall, it falls either ahead of time or comes too late or even stops rain in short period of mid-season. Hence, the required amount is not available at the right time (MoWR, 2002).

2.17.1. Socio-Economic Causes of Water Scarcity

Developing countries have been experiencing population growth which affects water availability. Access to water is also further complicated by conflicts arising over the right to access water sources (WHO, 2003).

2.17.1.1. Growth in Population

Freshwater is a finite and precious resource that is essential for sustaining life. Water is needed in all aspect of life. As demand increases, water resources are increasingly scarce (Winpenny, 2006). Therefore, among the greatest single influence on freshwater availability is the number of people competing for the resource. Higher population size and improved standards of living boost the demand for finite quantity of fresh water resource. This increases competition and tension among water users on few water sources. Over concentration of people and livestock in small areas will lead to the eruption of more conflict as people start to compete and fight over the limited water resources. In the dry season, the borehole is the only source of water for

pastoralists. Unless the balance between recharge and discharge managed properly, extracting more water from borehole may bring the possibility of exhausting the limited groundwater resources which gets annual replenishment from erratic rainfall in these regions (Omsa, 2005).

2.17.1.1. Coping Strategies Water Scarcity

The reactive or proactive action and the categories of measures that can be taken in the strategic planning process (either supply related or demand related) could be applied as measures to mitigate water scarcity. Long-term actions or proactive approaches oriented to reduce the vulnerability of water supply system to drought; i.e. to improve the reliability of each system to meet future demand under drought conditions by a set of appropriate structures and institutional measures. These long-term actions may or may not completely eliminate risk associated with it. They are supplemented by short-term measures which try to face incoming particular water scarcity events within the existing framework of infrastructures and management policies. Short-term measures correspond to the actions taken during what is called contingency plan.

The measures related to supply management aim at increasing the available water supplies whereas those pertaining to demand management aim at improving the efficient use of the available water resources. These two categories of measures intended to reduce the risk of water shortage due to drought events (Mohammed, 2002).

2.16. Environmental Sanitation

The World Health Organization (2000), defined sanitation as a group of methods to collect human excreta and urine as well as community waste waters in a hygienic way, where human and community health is not altered. Sanitation methods aim to decrease the spread of diseases by adequate wastewater management, excreta and other waste treatment; proper handling of water and food and by restricting the occurrence of causes of diseases. Sanitation is a system to increase and maintain healthy life and environment. Its purpose is also to assure people enough clean water for washing and drinking purposes. Typically health and hygiene education are

connected to sanitation in order to make people recognize where health problems originate and how to better sanitation by their own actions.

Urban environmental management addresses issues of environmental problems that exist in the urban area. Sanitation is one of the most basic services in human life. However, the provision of this service is very poor in developing countries, like Ethiopia. Only small percent of the households use pit latrines in Ethiopia, the rest being too poor to build their own toilets they use open fields. This causes a negative effect on the assimilative capacity of the environment and contributes to health problems. Mechanisms of reducing these problems could be providing sanitation services for the public by either the government or private organization. For both cases valuation of the willingness to pay of the people to use this service is important.

According to some studies, “this poverty is exacerbated by environmental problems that account for a large share of ill health, early deaths and hardship, particularly in low-income cities and neighborhoods.”

According to a study on water and environmental sanitation, “Environmental sanitation is a term that includes issues like safe excreta disposal, solid waste management, medical waste management, wastewater management, site drainage, personal hygiene facilities, vector and pest control and food hygiene.” Although, all the sanitation facilities are important, this study focuses on the personal hygiene facilities.

The inappropriate use of the environment for sanitation decreases the assimilative capacity of the environment; which is one of the three services provided by the environment. If this situation continues it will reduce the carrying capacity of the environment. Furthermore, most of the health problems are caused by the poor quality of the environment. For example, a study showed that “over two million children die each year of diseases that result from poor quality drinking water and inadequate sanitary facilities.”

According to Beyene et, al., (2015), The sanitation coverage is far from the MDG target and the majority of the population, mainly the urban poor, are living in a polluted environment, exposed to water and sanitation-related diseases. The sanitation coverage estimates might be even lower if proper utilization, regular emptying, and

fecal sludge management (FSM) of dry pit latrines were considered as indicators. In order to enhance sanitation services for all in the post-MDG era, urgent action is required that will establish proper monitoring and evaluation systems that can measure real access to Improved Sanitation Coverage (ISC).

The data from the nationwide inventory of sanitation facilities, which are presented along the sanitation ladder, reveal that more than half of the Ethiopian population (52.1%) still used unimproved sanitation facilities in 2014. The majority (35.6%) practiced open defecation, implying that the country is far from the MDG target for access to improved sanitation (56%). Most people in urban slums (88.6%) used unimproved sanitation facilities, indicating that the urban poor did not receive adequate sanitation services.

According to MOH (2011), sanitation refers to the hygienic principles and practices relating to the safe collection, removal or disposal of human excreta, refuse and wastewater, as they impact upon users and the environment. National sanitation task team also defined adequate sanitation as about both physical facilities (toilets and associated system requirements) and practice.

Sanitation is the hygienic means of preventing human contact with the multiple hazards associated with waste in order to promote health. Some of the hazards include physical, microbiological, biological and chemical. The most common hazards that pose health problems originate from human and animal feces, solid waste, domestic wastewater, and industrial and agricultural waste. To prevent the health threat posed by these wastes, engineering solutions such as sewage and wastewater treatment and simple technologies like latrines, septic tanks or even hand washing with soap rank high. Environmental sanitation is the control of environmental factors that form links in disease transmission, for example, solid waste management, water and wastewater treatment and industrial waste treatment.

World Health Organization defines sanitation as group of methods to collect human excreta and urine as well as community wastewaters in a hygienic way in order to decrease the spreading of diseases by adequate wastewater excreta and other waste treatment, proper handling of water and food and by restricting the occurrence of causes of diseases (Korkeakoski, 2006).

Korkeakoski, (2006), also stated that the purpose of sanitation is assuring people enough clean water for washing and drinking. Typically, health and hygiene education are connected to sanitation in order to make people recognize where health problems originate and how to better sanitation by their own actions. An essential part of sanitation is building and maintenance education on sewerage systems, wash up and toilet facilities.

According to WHO/UNICEF, (2011), an improved sanitation facility is commonly defined as one that hygienically separates human excreta from human contact.

As stated by UN-HABITAT, (2006), a household is considered to have sufficient access to sanitation if a waste disposal system, either in the form of a private toilet or a public toilet (i.e. latrines at markets, bus terminals and lorry parks, patient and staff latrines at health facilities, teacher and pupil latrines at schools) shared with a balanced number of people, is available to household members.

The majority of the existing toilets in urban areas of Ethiopia are simple pit latrines, which face a variety of problems like pit collapsing and flooding. Also, the need for digging of new pits once the old one is filled is considered a drawback of this conventional technique. The use of septic tanks is impeded by factors like the lack of dislodging facilities (e.g. Vacuum trucks) and missing sludge management concepts (Meinzinger, Oldenburg and Otterpohl, 2008).

As reported by (UNICEF, 2006), in Ethiopia, it is estimated that more than 250,000 babies die each year from poor sanitation, hygiene (compared to the estimated 500,000 children who die each year due to preventable diseases and malnutrition.

According to UNICEF, (2008), Although institutions such as the World Bank and UNICEF have dedicated considerable resources to improving sanitation around the world, 51 countries, including Ethiopia, are at risk of not meeting their sanitation target within the Millennium Development Goal number 7 for environmental sustainability.

As reported by UNICEF, (2008), it is estimated that approximately 2.4 billion people will remain without adequate sanitation facilities by 2015. Poor sanitation increases the risk of faecal-oral transmission and is a major risk factor in exposing children to pathogens and infectious diseases. These pathogens and diseases can cause severe

diarrhea that claims up to 2.2 million lives per year worldwide even where there are no symptoms, related diseases can prevent the absorption of nutrients necessary for growth and development.

As reported by AMCOW, (2011), the state of urban sanitation in Ethiopia differs substantially depending on coverage estimates used. Based on the JMP definition of improved facilities, urban coverage is only 29 percent (with a higher number using shared facilities), while government figures, which include a broader range of sanitation facilities in the coverage estimate (such as traditional pit latrines), estimate coverage as 88 percent.

2.17. Sanitary Inspection of Water Sources

According to WHO, (1997), in the case of groundwater, like protected springs and wells and protected water connection system, it should be possible to achieve very low levels of contamination however, different protected water sources are highly subjected to bacterial contamination, due to various reasons.

As stated by WHO (1997), evaluation checklist which has a score of the risk out of ten (9-10=very high risk, 6-8=high risk, 3-5= intermediate risk, and 0-2=low risk. The following are included in the checklist: the physical status of protection box, the situation of the outlet and overflow pipe the drainage system and the general sanitation of the springs. Springs with a high sanitary risk score had an inferior bacteriological quality, and on the contrary, those springs with low sanitary risk score found to have good quality. Liyod also indicated the higher hazard score of protected springs generally correlate well with increasing order of magnitude of faecal contamination (Lioud, 1992).

The result of sanitary and quality monitoring in a pilot water quality surveillance study in Sirilanka demonstrated that 65.0% to 85.0% of public water supplies; mostly springs become faecally contaminated because of poor site selection, protection and unhygienic management of facilities (Mertens,1990). A Study conducted in rural Zambia showed that poor community sanitary practices around the source and in the catchment area together with the failure of in the protection of water sources contributed to the contamination of drinking water (Sutton and Dominic, 1989). Similarly, a study conducted in South Wollo, Ethiopia, clearly showed an improper

sanitary survey and, failure in the protection of water sources together with poor community sanitary practices around the source and in the catchment area contributed to the contamination of drinking water with faecal matter (Tiku, Legesse. and Kebede 2003).

2.18. Environmental Sanitation and Communicable Diseases

Access to qualitatively good drinking water, adequate sanitation facilities and services and satisfactory hygiene practices significantly contribute to reducing the rate of morbidity and mortality among populations. Numerous studies indicate a direct link between environmental health risks and limited access to clean water, sanitation facilities and services on the one hand, and poor hygiene practices on the other. This leads to negative health impacts, environmental degradation and related economic impacts on the affected population. There are a number of diseases related to excreta and wastewater which commonly affect people in the developing countries and which can be subdivided into communicable and no communicable diseases (Franceys et al,1992).

Table:

Conditions	Diseases
Lack of an adequate and safe water supply	Typhoid fever, cholera , hepatitis, gastrointestinal diseases, a number of parasitic diseases, trachoma and skin infections.
Insanitary disposal of excreta	Infantile diarrhea, gastrointestinal infections, cholera and parasitic diseases
Inadequate disposal of solid wastes	Gastrointestinal and parasitic diseases and leptospirosis
The absence of or inefficient drainage of surface waters	Encourages vector breeding and infections due to contact with contaminated water.
Inadequate personal and domestic hygiene and	Increases risks of the faecal-oral, skin, eye and vector-borne infections
Poor food safety practices	Gastrointestinal and diarrheal diseases and malnutrition

Sources: World Health Organization 1991.

All of the transmission routes of excreta-related diseases particularly the faeco-oral routes can be blocked by changes in domestic hygiene practice. Improved technologies, such as water and excreta disposal facilities, can also contribute to preventing transmission (Curtis et al, 2000).

Environmental health interventions for the prevention of diarrheal disease typically include steps to improve the proper disposal of human faeces (sanitation), improving water quality, water quantity and access, and promoting hand washing and other hygiene practices (Clasen et al, 2010).

The primary water pollution problem in the world is lack of clean, disease-free drinking water. The occurrence of disease may quickly and surprisingly occur (Keller, 2009). Experience has shown that microbial hazards continue to be the primary concern in both developing and developed countries (WHO, 2004). The great majority of evident water-related health problems are the result of microbial (bacteriological, viral, protozoan or other biological) contamination (WHO, 2008).

Some improved water systems may start with water that is microbiologically safe. However, once the water has flowed past cracked wellheads and casings, through poorly maintained pipes laid adjacent to sewer pipes, and has been subject to low and sometimes negative water pressure and other flaws, it is not surprising that the water is often contaminated by the time it reaches the point of collection. As the water is carried home and stored, it can be further compromised by hands and utensils that are dipped into the bucket and by other intrusions. The end result is that the water may be heavily contaminated at the moment it is consumed, even if it started out as potable (Choffnes and Rapporteurs, 2009).

The provision of potable drinking water for rural and urban areas is necessary to prevent the dangers of water diseases and public health prevention. Potable water has to comply with certain physical, chemical and microbiological standards which should not contain microorganisms and chemicals at harmful levels (Sartaj, A. 2013, Arunabh, M, Vasishta B, 2008).

According to WHO, (2011), Waterborne diseases are the most hazardous ones in terms of public health, because they can easily spread water born diseases are caused by pathogenic microorganisms that most commonly are transmitted in

contaminated water, water born disease account for 4.1% of the total daily global burden of disease and cause about 1.8 million human deaths annually. The WHO (2011), estimates that 88% of the total burden is attributable to unsafe water supply, sanitation, and hygiene (Tya, Umaru and Barmamu 2014).

The majority of the populations in developing countries including Ethiopia, is not adequately supplied with potable water and is thus compelled to use water from alternative water sources like hand dug and shallow wells, rivers, ponds and streams that render the water unsafe for domestic and drinking purposes due to high possibilities of contamination and risks of water-borne diseases are therefore a major public health concern in these countries (WHO, 2011, Ayantobo, Oluwasanya, Idow, and Eruola,2013).

Polluted water is potentially dangerous to health because of possible outbreaks of dysentery or cholera, epidemics and other water born disease because these alternative water sources like hand dung wells provide cheap and low technology solution to the challenge of rural-urban water supply and their construction also vulnerable for introduction of agricultural and domestic wastes due to lack of afford an opportunity for community participation during all phases of the water supply process (Dagnew *et al*, 2010).

According to UNICEF/WHO (2009), unsafe drinking water, along with poor sanitation and hygiene, are the main contributors to diarrheal diseases. Every year 2.5 billion cases of diarrheal likely to result in death or other outcomes occur among under-five children (Christa, 2010). More than half of these cases occur in Africa and South Asia and Diarrhea remains a major cause of mortality in children under 5 years of age in Sub-Saharan countries in Africa.

Studies and reports on child morbidity and mortality in Ethiopia show that diarrhea is the major public health problem (Mekasha and Tesfahun, 2003). According to 2010 reports of the federal ministry of finance and Economic development, 20% of childhood death in the country was due to diarrhea (MOFED, 2010). In 2011, EDHS reported that 13% of the children had diarrhea in the two weeks preceding survey at the national level (CSA, 2007).

As reported by UNICEF in (2008), diarrheal diseases reduce normal ingestion of foods and absorption of nutrients, sustained high morbidity also contributes to malnutrition, a separate cause of significant mortality; it also leads to impaired physical growth and cognitive function, reduced resistance to infection, and potentially long-term gastrointestinal disorders. Contaminated drinking water is also a major source of hepatitis, typhoid and 6 opportunistic infections that attack the immuno-compromised, especially persons living with HIV/AIDS.

According to WHO/ UNICEF in (2013), the four categories of water-related diseases are water-borne, water- washed, water-based and water-related insect vectors. The water-borne pathogen is acquired through consumption of contaminated water, as occurs in diarrheal diseases, dysentery and typhoid fever and water-washed pathogen is spread from person to person due to lack of water for hygiene, as occurs in diarrheal diseases, scabies, and trachoma. Water-based pathogen is transmitted to humans through contact with infection, multiplication in, and excretion from aquatic intermediate hosts, as occurs in the diseases schistosomiasis and Guinea worm and water-related insect vectors pathogen is carried and transmitted by insects that breed in or bite near water, as occurs in Dengue fever, Malaria, and Sleeping sickness. However, diarrheal diseases, which are faecal-oral, are responsible for the greatest number of episodes of illness and deaths worldwide, compared to any other single classification of water and sanitation-related disease (Choffnes and Rapporteurs, 2009).

2.19. Needs of Water Supply and Sanitation

According to ADF (2005), the need for quality water and sanitation is widely recognized as an important element of social and economic growth. The provision of water and sanitation services addresses some of the most critical needs of people. Safe water and good sanitation are essential to the protection of community health by preventing the transmission of infectious diseases and by supporting and preservation of a sanitary home environment. At the same time, they contribute greatly to the enhancement of human dignity and economic opportunity by relieving the burden of women and children, from the drudgery of water carrying and providing more time for them to engage in other activities.

Report from ADF (2005), revealed that accessibility of improved and quality water supply and sanitation infrastructures is widely recognized as a vital part of human rights, social and economic progress. Access to water is a prerequisite for health and livelihood, which is why the MDG target is formulated in terms of sustainable access to affordable drinking water supply.

Although improved water sources are available, they are often far away from the beneficiary households and are located at inconvenient locations. The management system of stakeholders coupled with water quality problems and inaccessible water sources are some of the basic problems (Demeke, 2009; Bhandari and Grant, 2007).

As reported by Demeke in (2009), the topography of Ethiopia is characterized by rugged landscapes on which women and children travel long distances by carrying large containers up and down steep slopes; In addition to this, the lack of safe water supply has other series negative consequences such as the workload in fetching unsafe water from mostly distant unimproved or traditional water points make them exposed to health problems.

Basic access to water can be defined as the availability of drinking water at least 20 liters per day per person, a distance of not more than 1 km from the source to the house and a maximum time taken to collect round trip of 30 minutes. The UNDP (2006) says the minimum absolute daily water need per person per day is 50 liters (13.2 gallons) which include: 5 liters for drinking, 20 for sanitation and hygiene, 15 for bathing and 10 for preparing food. However because of the scarcity of drinking water, millions of people try to exist on 10 liters (2.6 gallons) a day (ADF, 2005). In densely populated areas, a water hauling trip of 30 minutes or less, including queuing time would be a more appropriate indicator of access.

As indicated by ADF, (2005), over one-third of women in some of the regions spent more than two hours for each water collection trip. This fact is aggravated by the poor supply efficiency.

According to Collick (2008), the high demand for water due to large family size leads to household water insecurity (less water available than is needed for drinking, cooking, and sanitation) in rural areas, especially for those households for which the

demand is higher due to large family size and because of these conditions, it is difficult to think about personal hygiene and sanitation especially for the rural communities. Despite the scarcity of water, many give priority for drinking and cooking purposes. Rural communities use unprotected springs and hand-dug wells commonly for cooking and drinking purposes. As reported by Sobsey, (2002), in addition to these rivers are also used for drinking purposes. This results in not only sickness and death but also economic crises. Therefore, safe drinking water is an essential component of primary health care and is vital for poverty alleviation. Introducing improved water supply sources at the household level enhance personal and community knowledge as well as awareness of the importance of other factors, such as hygiene and sanitation.

2.20. Water Security, Sanitation, and Poverty

Water security is the key to address the water crisis in the 21st Century. It means that people and communities have reliable and adequate access to water to meet their different needs, are able to take advantage of the different opportunities that water resources present, are protected from water-related hazards, and have fair recourse where conflicts over water arise.

The concept of water security is based on the creation of mechanisms that ensure the poor have secure and sustainable access to water resources, which in turn means strong links to participation and the governance conditions that dictate this access. Central to this is the recognition of the needs of all users, as well as the value and potentials of all uses of water resources in decisions about their future. Water resources (including aquatic plants and animals, hydropower, and aesthetic as well as other services) come from many sources (including surface and groundwater) and have many uses: domestic needs, irrigation, fishing, industry, waste disposal, etc. Securing access to water for human consumption, hygiene, and productive uses are central to tackling poverty and food insecurity and increasing resilience across sub-Saharan Africa (SSA). An inability to access enough water without spending excessive time or money or facing personal risk, and the unreliability of water for crops and livestock, helps to keep millions in poverty. This is rarely because of

absolute water shortages, at least for domestic needs; it is the result of inadequate investment to ensure reliable access for all.

Poor water access undermines food security (food availability, access, and absorption) via three principal routes at the household level (Tucker and Yirgu, 2011; Calow et al., 2010)

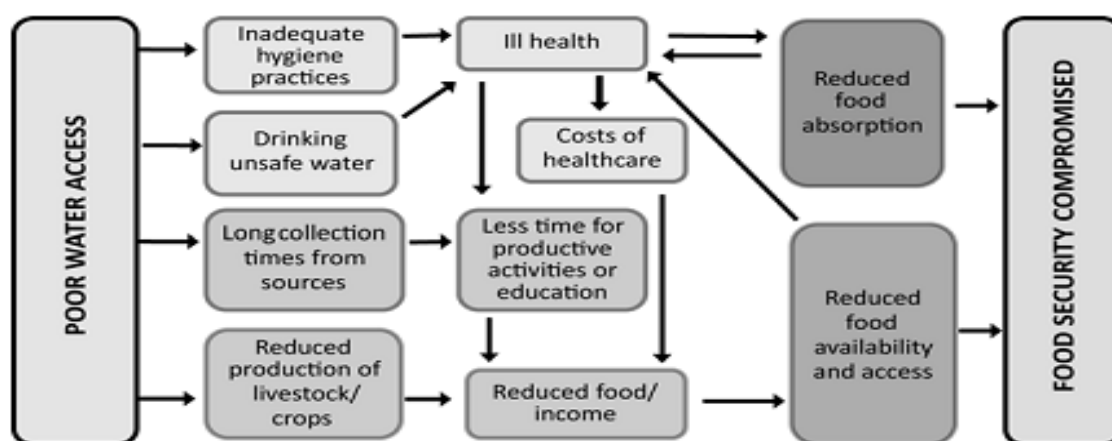


Figure 15: Causal pathways linking lack of water with food insecurity

Source: adapted from Tucker and Yirgu, 2011

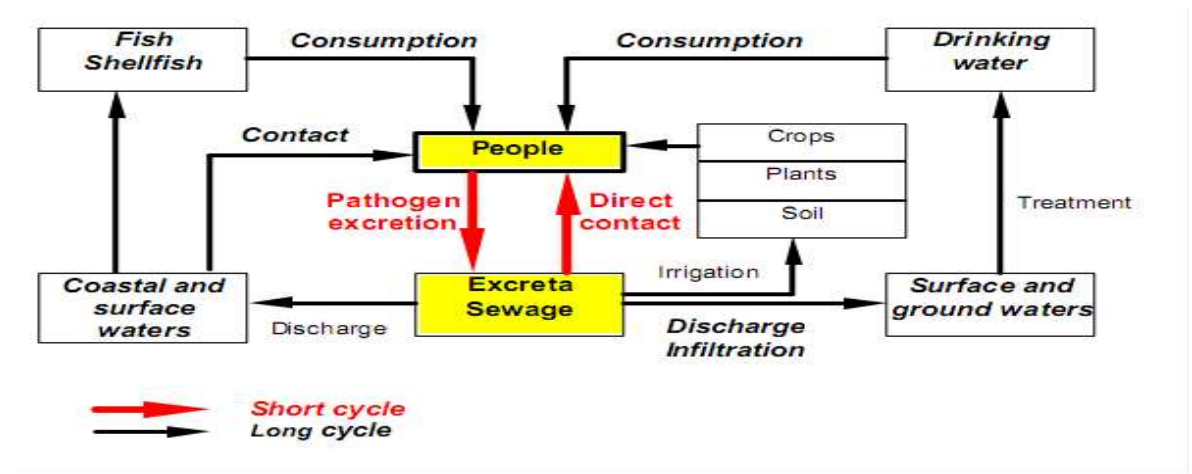
The clear need for basic water and sanitation services for the poor assumes even greater significance when the linkages with other dimensions of poverty are considered. Water and sanitation-related sicknesses put severe burdens on health services and keep children out of school. Human waste poses a tremendous social cost through pollution of rivers and groundwater.

Inadequate water and sanitation services to the poor increase their living costs, lower their income earning potential, damage their well-being and make life riskier. The continuing, nearly universal deterioration of the surface and underground water sources on which people survive means that water and sanitation pressures will simply become worse in the future.

2.20.1. Health Effects

The improvement of water and sanitation in developing countries is largely driven by the need to reduce the incidence and prevalence of infectious disease caused by pathogenic microorganisms.

The majority of pathogens that affect humans are derived from faeces and transmitted by the fecal-oral route. Pathogen transmission may occur through a variety of routes, including food, water, poor personal hygiene and flies (Christophe Bosch *et al.* 2001).



Source: Christophe Bosch et al. Water, Sanitation, and Poverty, 2001

Figure 16 : **The Main Pathways of Human Exposure to Pathogens in the Aquatic Environment**

According to USAID Statement of Work for the Millennium Water Alliance Water, Sanitation & Hygiene (WASH) program evaluation, “approximately 3.1% of deaths worldwide are attributed to unsafe water, sanitation and hygiene practices. Africa carries the heaviest burden, with 4 to 8% of all disease in Africa being related to poor water, sanitation and hygiene. In Ethiopia, water and sanitation-related diarrhea account for approximately 20% of all deaths in children under the age of five, taking the lives of close to 100,000 children annually.

Thirty-two percent of this diarrhea could be prevented by improving sanitation interventions such as pit latrines, septic tanks and composting toilets” (USAID, 2013).

2.20.2. Environmental Degradation

2.20.2.1. Impacts

According to MoH, (2011), pollutants of surface waters such as faeces and urine are a potential source of compost and fertilizer which could help address increasing soil fertility and reduce the high cost (both financial and environmental) of chemical fertilizers. They can also be used to produce biogas (a renewable energy source) which contributes to reducing deforestation; which is a key environmental issue. Biogas digesters can also be ‘fed’ with organic solid waste in urban areas as an effective treatment and use of ‘waste’.

2.20.2.2. Effects on Education

In some cultures, the lack of toilets in schools serving the poor is known to be a major factor in deterring girls from continuing their education, particularly after puberty. In these cultures, private toilets (if only latrines) and even the availability of drinking water provide a necessary condition to reach school enrollment goals.

On another dimension, children – particular girls – are often required to help their mothers with the time-consuming task of fetching water. Fetching water has been found in many countries to reduce children’s time for schooling or playing.

2.21.2.3. Effect on Women, Children, and Education

According to UN Habitat, (2010), African women are relatively burdened by scarcity of clean drinking water.

As indicated by Joint Monitoring program for water supply and sanitation in (2010), most African societies, women are seen as the collectors, managers, and guardians of water, especially within the domestic sphere that includes household chores, cooking, washing, and child rearing. Because of these traditional gender labor roles, women are forced to spend around sixty percent of each day in collecting water, which translates to approximately 200 million collective work hours by women globally per day. For African women, this often means carrying the typical jerrycan that can weigh over 40 pounds when full. As a result of this, many women are unable to hold professional employment. Additionally, this prevents

many young girls from attending school and receiving an education. They are expected to not only aid their mothers in water retrieval but to also help with the demands of household chores that are made more time-intensive because of a lack of readily available water. Furthermore, a lack of clean water means the absence of sanitary facilities and latrines in schools, and so once puberty hits, this has the largest impact on female children. In terms of lost educational opportunity, if adequate investment were made in drinking water and sanitation, it is estimated that it would result in 272 million more school attendance days per year. (UN Habitat, 2010).

This lost number of potential school days and education results in the hindrance of the next generation's African females from breaking out of the cycle of unequal opportunity for gainful employment. Because of this, available clean water for women and children translates to Africans with potential for education, prosperity, power, literacy, hygiene, security, and equality (UN Habitat, 2010)

A lack of adequate sanitation will endanger girls and women in those cultures where they have to wait until the evening to be able to defecate and urinate.

2.21.2.4. Effects on Productivity and Development

As stated by WHO (2007), poverty is directly related to the accessibility of clean drinking water. The social and economic consequences of a lack of clean water go through into area of education, opportunities for gainful employment, physical strength and from health, agricultural and industrial development, and thus the overall productive potential of a community, nation, and/or region. Because of this, the UN estimates that Sub-Saharan Africa alone loses 40 billion potential work hours per year collecting water. Because of this, the United Nations Development Programme estimated that in Africa, every dollar spent on water and sanitation generates a nine-fold return in saved time, increased productivity and reduced health cost.

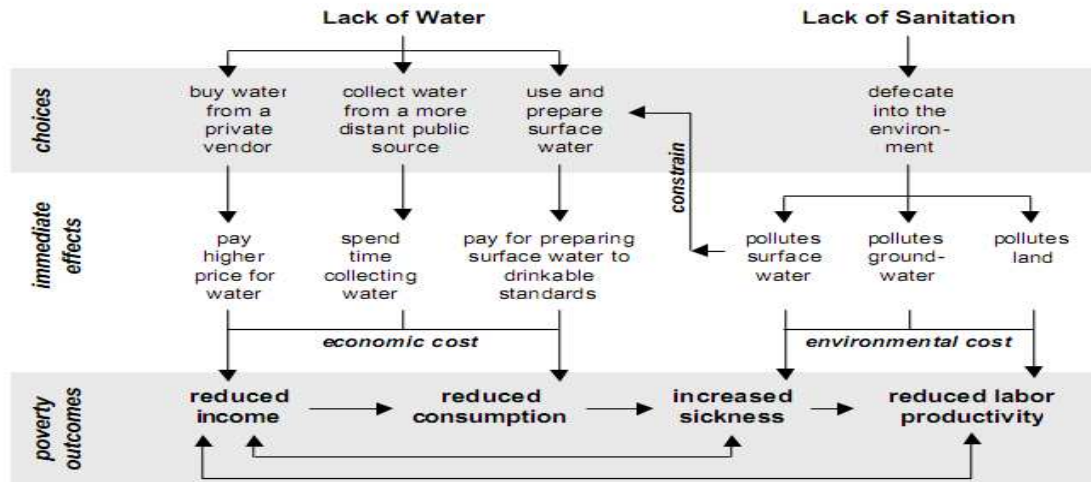


Figure 17: *Consumption and Income Effects* (Sources: Christophe Bosch *et al.* Water, Sanitation, and Poverty, 2001)

The lack of convenient and affordable access to water reduces a poor household's consumption of other commodities and services, leaves it consuming less than the optimum amount of water for good hygiene, and impacts health and labor productivity of the household members. It may also reduce income-generating opportunities of the household; thereby further reducing income and consumption.

Threats to water sustainability arise in both quality and quantity dimensions, driven by pollution and competing demands from many sectors, including industry, agriculture, and energy. Environmental degradation reduces labor productivity by contributing to the increased burden of diseases and by limiting income potentials (especially in aquaculture).

Nationally, dwindling availability of clean water per capita will increase the economic cost of water and, in a situation of scarcity, limit the potential for economic development. Locally, communities that fail to protect their surface and ground waters from pathogens have fewer options for drinking water and require more expensive technologies for extracting water from deeper aquifers or for treating surface water to drinkable levels.

2.21. Sanitation and Hygiene in Ethiopia: Status and Targets

Provision of an adequate supply of safe water and basic sanitation is a primary health activity an integral part of the national health systems, This reflects the key role of improved Sanitation & Hygiene practice in preventing tropical diseases and mortality from diarrhea (Mara *et al.*, 2010).

According to MoH (2010), 60 percent of the total population of Ethiopia has access to sanitation facilities (56 percent in rural areas), although only 20 percent of households actually utilize latrines Estimates published internationally are, however, much lower. According to information supplied by the Ethiopian Government, the 2012 report of the World Health Organization (WHO)/United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP) estimated rural sanitation access, including basic and shared facilities, at 47 percent in 2010, up from 29 percent in 2008 (WHO/UNICEF, 2010; 2012).

2.22. The Sustainable Development Goals on Water and Sanitation

Ensure Availability and Sustainable Management of Water and Sanitation for all

According to WHO and UNICEF (2017), Everyone on earth should have access to safe and affordable drinking water. That's the goal for 2030. While many people take clean drinking water and sanitation for granted, many others don't. Water scarcity affects more than 40 percent of people around the world, and that number is projected to go even higher as a result of climate change.

If we continue the path we're on, by 2050 at least one in four people are likely to be affected by recurring water shortages. But we can take a new path—more international cooperation, protecting wetlands and rivers, sharing water-treatment technologies—that leads to accomplishing this Goal.

Water scarcity affects more than 40 percent of people around the world, an alarming figure that is projected to increase with the rise of global temperatures as a

consequence of climate change. Although 2.1 billion people have gained access to improved water sanitation since 1990, dwindling supplies of safe drinking water is a major problem impacting every continent.

In 2011, 41 countries experienced water stress; ten of them are close to depleting their supply of renewable freshwater and must now rely on non-conventional sources. Increasing drought and desertification is already exacerbating these trends. By 2050, it is projected that at least one in four people are likely to be affected by recurring water shortages.

Universal access to clean water and sanitation is one of 17 Global Goals that make up the 2030 Agenda for Sustainable Development. An integrated approach is crucial for progress across the multiple goals.

Targets for Goal 6

Goal 6 seeks to “ensure availability and sustainable management of water and sanitation for all”. It is a comprehensive goal addresses the entire water cycle, from access to use and efficiency, and the integrated management of water resources and water-related ecosystems.

Based on this UNICEF’s work on WASH will contribute to three main targets:

Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all

Target 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

Target 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

Improving accountability: the lack of sustainability of WASH interventions is a major barrier to universal access. Currently 30-50% of WASH projects fail after 2-5 years. In many cases, it is not the technical aspect that causes the failure, but rather a lack of good governance that compromises public-service delivery (WHO and UNICEF 2017).

SDG-6: Ensuring availability and sustainable management of water and sanitation for all: The development objectives of the water and sanitation sector comprise ensuring sustained supply of potable water and sustainable sanitation/sewerage disposal system; supplying water for use in industries and large irrigated agricultural development works and participatory watershed development & conservation to ensure sustained use of water resources. Rural potable water supply coverage increased from 59 percent in 2014/15 to 61.1 percent in 2015/16. The water systems reported are the 'improved water systems/schemes'. Urban piped-potable water supply coverage increased from 51 percent in 2014/15 to 52.5 percent in the 2015/16 fiscal year. National (Urban and Rural total) potable water supply coverage increased from 58 percent in 2014/15 to 61 percent in fiscal year 2015/16. Non-functional rural potable water supply schemes showed marginal change from 11.2 percent in 2014/15 to 11 percent in fiscal year 2015/16. Potable water supply and sanitation/sewerage coverage and the performances thereof could be said to be at rather low level and therefore deserve increased attention/focus (WHO and UNICEF ,2017).

Overview of the Ethiopia's vision and targets for the SDGs

As reported WHO and UNICEF(2017), the new Sustainable Development Goals (SDGs) were endorsed by the UN General Assembly in September 2015, setting ambitious new goals and targets for 2030. SDG goal 6, to 'ensure availability and sustainable management of water and sanitation for all' reflects substantially increased ambition for improving access to the unserved as it is now a goal of universal access, requiring the progressive reduction of inequalities and including hygiene in addition to water and sanitation . The inclusion of such targets reflects a recognition of central importance of basic water, sanitation and hygiene (WASH) for

a healthy and dignified life, and the ratification of the human right to drinking water and sanitation.

The water, sanitation and hygiene sector in Ethiopia is guided by the One WASH National Program (OWNP), National Hygiene and Environmental Health Strategy and Integrated Urban Sanitation and Hygiene Strategy and School Wash strategy. (2013- 2020). The strategy prioritizes the elimination of open defecation by 2023 and achieving universal access to safe water services by 2030 and 82% improved sanitation by 2020.

Ethiopia has a vision of achieving 100% of basic ***Water and Sanitation and*** to meet expected target for safely managed. WASH. To achieve these targets, ***Ethiopia*** will require more than US\$2 billion annually. Currently, the financing gap is estimated as 60 - 70% of ***SDG*** requirement.

In 2015, Ethiopia achieved the MDG Target coverage of 57.2% for water and 28% for sanitation. This was partly sufficient to achieve the MDG targets for water and significant progress on sanitation. The more ambitious WASH targets and standards under the SDGs significantly raises the bar for what is required. The main challenges are limited multi-year funding to reach the ambitious target, poor quality services for the poor in urban and rural areas, mainly in the area of sanitation and hygiene. Coverage and quality of services are lower among vulnerable groups including the underserved areas (WHO and UNICEF ,2017).

Ethiopia was praised in the global WASH JMP report of 2015 as having made the most remarkable progress in terms of sanitation coverage. From just 8% coverage in 1990, it had increased to 71% in 2015, 25 years later. “Open defecation was practiced by 44.3 million Ethiopians in 1990 and 28.3 million in 2015 – an average reduction of over 4 percentage points per year over 25 years” (JMP, 2015).

This significant achievement by the country has largely been enabled by the Government’s implementation of the Community led Total Sanitation and Hygiene approach (CLTSH) which was adopted formally by the Federal Ministry of Health (FMoH) in 2011 and rolled out across the country through the health extension

programme. UNICEF has supported the FMoH throughout the process of developing the strategy, the roll-out of training and the implementation of CLTSH across Ethiopia.

2.22.1 Progress on Drinking Water, Sanitation and Hygiene

According to WHO and UNICEF (2017), in 2015, 71 per cent of the global population (5.2 billion people) used a safely managed drinking water service; that is, one located on premises, available when needed and free from contamination.

- Eight out of ten people (5.8 billion) used improved sources with water available when needed.
- Three quarters of the global population (5.4 billion) used improved sources located on premises.
- Three out of four people (5.4 billion) used improved sources free from contamination.
- 844 million people still lacked even a basic drinking water service.
- 263 million people spent over 30 minutes per round trip to collect water from an improved source (a limited drinking water service).
- 159 million people still collected drinking water directly from surface water sources, 58% lived in sub-Saharan Africa.

In 2015, 39 per cent of the global population (2.9 billion people) used a safely managed sanitation service; that is, excreta safely disposed of in situ or treated off-site.

- 27 per cent of the global population (1.9 billion people) used private sanitation facilities connected to sewers from which wastewater was treated.
- 13 per cent of the global population (0.9 billion people) used toilets or latrines where excreta were disposed of in situ.

- Available data were insufficient to make a global estimate of the proportion of population using septic tanks and latrines from which excreta are emptied and treated off-site.
- 2.3 billion people still lacked even a basic sanitation service.
- 600 million people used a limited sanitation service.
- 892 million people worldwide still practiced open defecation

In 2015, 70 countries had comparable data available on handwashing with soap and water, representing 30 per cent of the global population.

- Coverage of basic handwashing facilities with soap and water varied from 15 percent in sub-Saharan Africa to 76 per cent in Western Asia and Northern Africa, but data are currently insufficient to produce a global estimate, or estimates for other SDG regions.
- In Least Developed Countries, 27 per cent of the population had basic handwashing facilities with soap and water, while 26 per cent had handwashing facilities lacking soap or water. The remaining 47 per cent had no facility.
- In sub-Saharan Africa, three out of five people with basic handwashing facilities (89 million people) lived in urban areas.
- Many high-income countries lacked sufficient data to estimate the population with basic handwashing facilities.

According to WASH Field Note (2017), in 2015, Ethiopia achieved its Millennium Development Goal target of 57 percent access to safe drinking water, an increase from just 13 percent in 1990. Yet access to improved sanitation, while also vastly improved since 1990, remains alarmingly low at only 28 percent nationwide. Overall, safe water, sanitation and hygiene (WASH) coverage across Ethiopia remains woefully inadequate. Communities without access to safe water depend on scarce and often seasonal surface water sources like unprotected springs, ponds, streams and rivers, many of which are located far from households and contain severe waterborne diseases. When drought conditions prevail, many of these water sources for people and their crops and livestock disappear.

A 2015-16 survey of Community-Led Total Sanitation and Hygiene (CLTSH) across 8 Regions of Ethiopia has found that open defecation continues to reduce across the country, now estimated at 32%. Much of this coverage remains ‘unimproved’ or basic, and the next big challenge, whilst continuing to accelerate progress, is converting this coverage to ‘improved’ or ‘safe’ sanitation. Whilst the implementation of CLTSH remains strong, the study findings suggest there are some key implementation adjustments which could improve the uptake of improved sanitation.

Ethiopia has reached the Millennium Development goal of access to safe water and the national coverage reached to 68.5% and 33% for sanitation facilities. Ethiopia is not on the right track to reach for sanitation target (47%) of 2015. The development trend for water coverage and sanitation facilities shows that urban dwellers (16% of the population) are more benefited than the rural (84%) citizens. Poor access of sanitation and improved drinking water in rural part is resulted due to improper planning, malfunction water scheme utilities, and other factors (Thewodros and Seyoum, 2016).

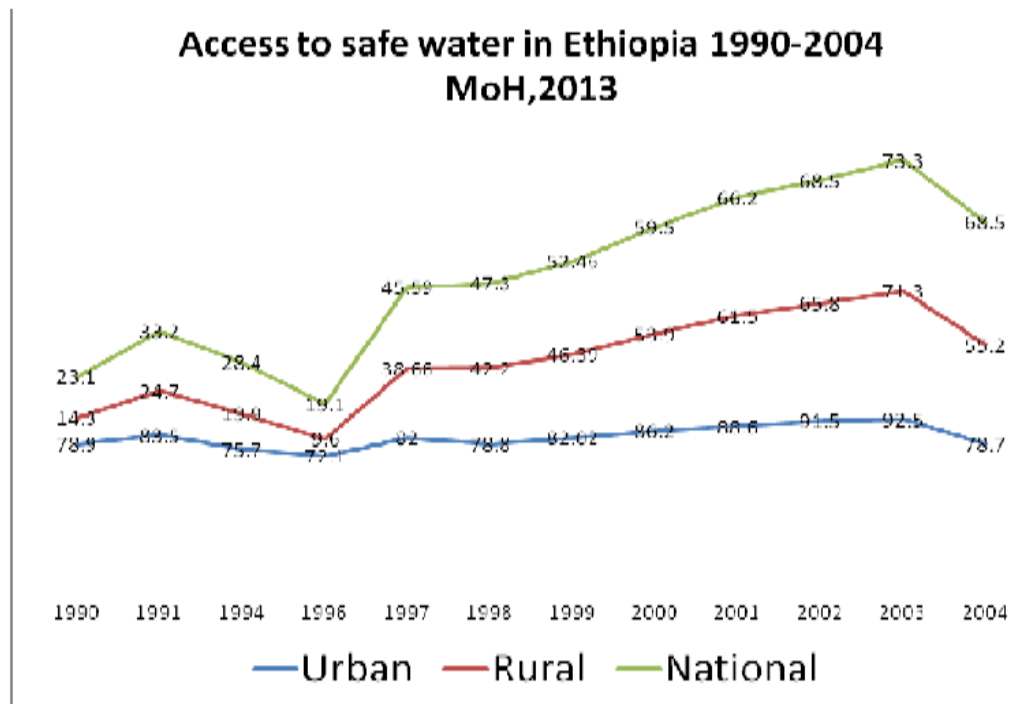


Figure 18: Trends in access to improved water sources coverage, in Ethiopia (1997-2012 GC). Source MoH & MoWE, 2013; Source; MoH& MoWE, 2013

In most parts of Ethiopia, the available drinking water has been challenged by different factors like population growth, urbanization. Access of the water should have to be calculated on the bases of the continued availability of within a given period of time than just the length of dry pipelines. In some part of Addis Ababa, drinking water is distributed on shifts. The same is true in most regional urban areas of Ethiopia. It will be challenging to answer that how accessibility is determined in the absence of water.

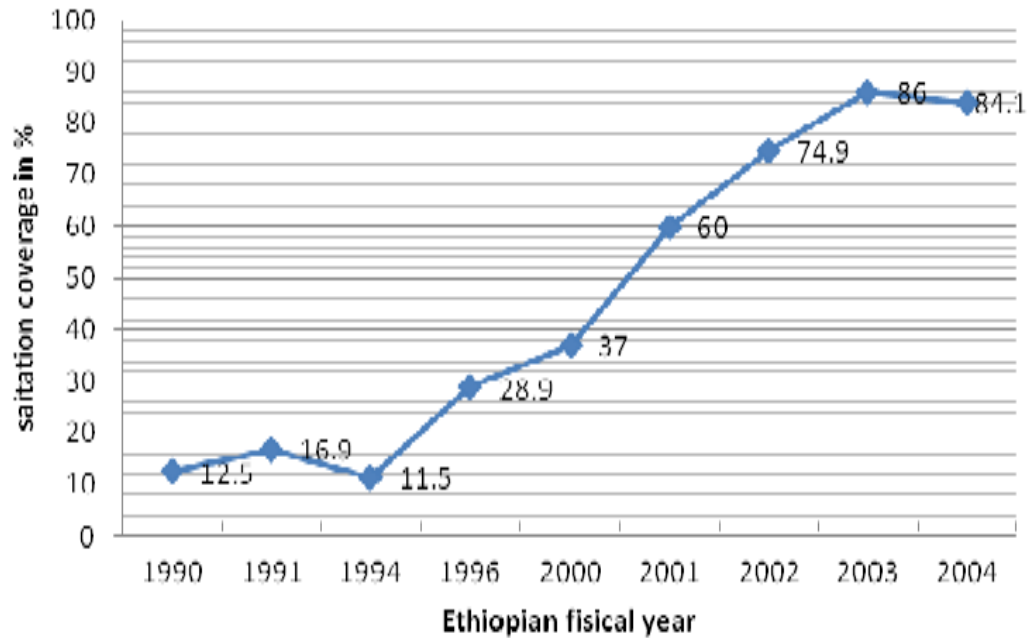


Figure 19: Trends in access to improved sanitation coverage, in Ethiopia (1990-2004EC) Source; MoH & MoWE, 2013.

Majority of Ethiopian citizens (81-85%) are living in rural part, the progress towards access safe water to rural part of Ethiopia (55.2%) is behind the urban population 78.7% in 2004 (Fig. 19).

According to UNICEF & WHO (2015), this shows that emphasis is given to the small proportion of the population (urban 15-19%) than the rural part or improper planning activities in the sector. In other words, it can be attributed to lack of political commitment, financial allocation and health benefits towards pro-poor policies, strategies. According to the recent update of WHO/UNICEF report (Fig. 21), piped line water premises was not available as the required level 51% of the rural community has access to unimproved source of water for their life activity. It is particularly encouraging to note that the proportion in rural areas with access to clean water has significantly increased from 4% in 1990 to 49% in 2015. In line with this safe drinking water access of the same period increased from 80% to 93% in urban areas for the same period.

Additionally, the relatively great difference on drinking water coverage estimates on improved source and piped line premises has been observed in urban dwellers.

Almost 93% of urban residents use to improve water source on other hand using the unimproved source of drinking water has decreased to 10% in 1990 from 7% in 2015. Because of the great drinking water coverage disparity between the rural and urban population the national coverage of improved water source usage reached 57% still 43% of the total Ethiopian citizen's relay of unimproved drinking water sources. 51% of the rural population still depends on unimproved drinking water sources for day to day activities (Figure 21).

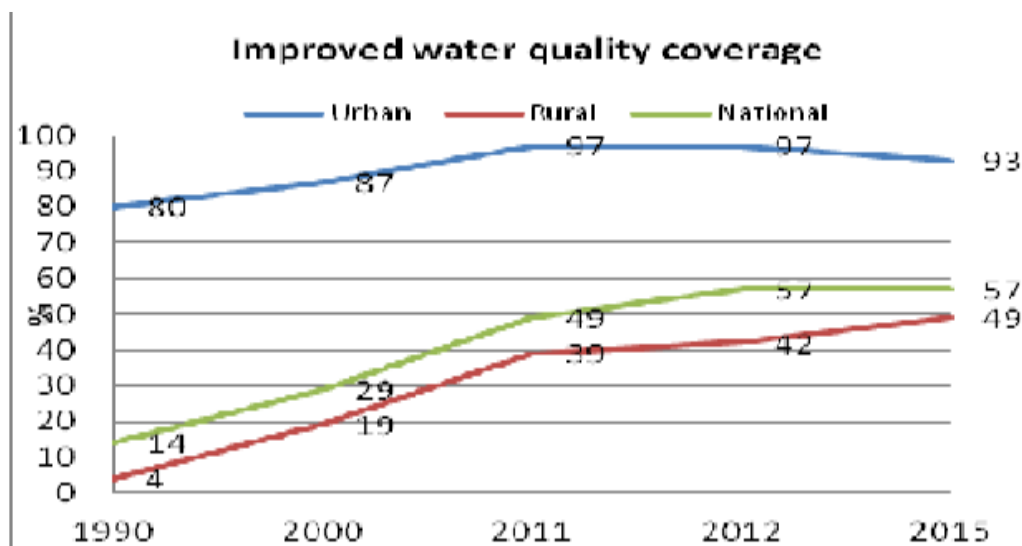


Figure 20: Estimated trends of use improved drinking water sources in Ethiopia. Source: WHO/UNICEF JMP, 2013, 2014, 2015. Source: WHO/UNICEF JMP, 2013, 2014, 2015

2.23. Access to Basic Sanitation

Based on the estimates of WHO/UNICEF JMP 2013-15, the overall access to basic sanitation in 1990 is low 98%. Closer to 34% of the rural and 6% of the urban population of Ethiopia exercised open defecation in 2015 with an average national percentage of 29%. The health extension program (HEP) and the expansion of education have played there part in the improvement in sanitation services. According to the reports of WHO/UNICEF (2015), it is only 28% of the total population at national level have access to improved sanitation. Open defecation is still a problem (29%) of the Ethiopian population at national level still exercising open defecation. The problem is much more severe in rural part 34% than the urban area (6%) (Figure 22)(WHO/UNICEF JMP, 2015).

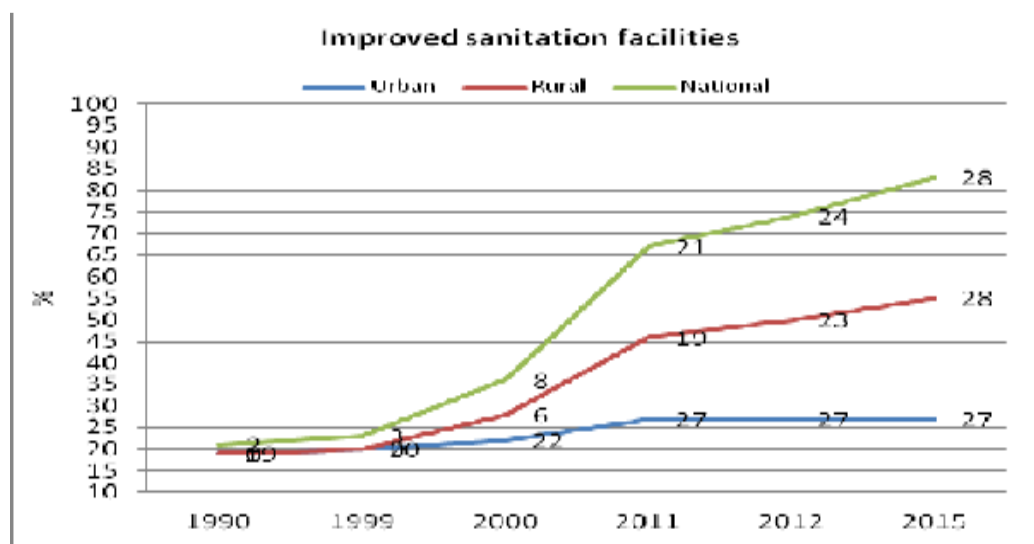


Figure 21: Estimated trends of use of sanitation facilities in Ethiopia Source: WHO/UNICEF JMP, 2013, 2014, 2015. Source: WHO/UNICEF JMP, 2013, 2014, 2015

2.24. Health and Water Quality

As stated by WHO in (2004), drinking or potable water, is defined as water having acceptable quality in terms of its physical, chemical, bacteriological parameters so that it can be safely used for drinking and cooking.

According to OECD (2012), water quality is mainly related to drinking water, hygiene, sanitation and human health. In many developing countries, water supplies are of poor quality often is unsafe for human consumption. Consequently, diseases will continue to spread among the poor until adequate wastewater disposal accompanies the provision of safe drinking water.

A report from WHO (2006), revealed that drinking water quality is a powerful environmental determinant of health. Drinking-water quality management has been a key pillar of primary prevention for over one-and-a-half centuries and it continues to be the foundation for the prevention and control of waterborne diseases. Millions of people are exposed to unsafe levels of chemical contaminants in their drinking water. This may be linked to a lack of proper management of urban and industrial wastewater or agricultural run-off water potentially giving rise to long-term exposure to pollutants, which can have a range of serious health implications. Or it may be

linked to naturally-occurring arsenic and fluoride, which cause cancer and tooth/skeletal damage, respectively (WHO, 2010).

Consumer perception and acceptability of their drinking water quality depend on user sense of taste, odor, and appearance (Doria 2010). Taste and odor can originate from various natural chemical contaminants, biological sources, and microbial activity, from corrosion or as a result of water treatment (WHO, 2004).

According to WHO (2004); WHO (2006), color, cloudiness, particulate matter and visible organisms can also contribute to the unacceptability of water sources. These factors can vary from each community and are dependent on local conditions and characteristics. More recently, the presence in groundwater of naturally occurring chemicals, such as arsenic and fluoride, has caused widespread exposure and unacceptable health effects in many countries.

Chemical contaminants of drinking-water are often considered a lower priority than microbial contaminants because adverse health effects from chemical contaminants are generally associated with long-term exposures, whereas the effects of microbial contaminants are usually immediate. Nonetheless, chemicals in water supplies can cause very serious problems. Drinking water quality has a strong impact on people's health because water is a vehicle of transmission for many pathogenic microorganisms that cause diarrheal diseases (WHO, 2004; WHO, 2006).

2.25. Benefits of Improving Access to Water and Sanitation

According to Postnote (2002), increasing access to water and sanitation is an input of development and poverty reduction, as it has major health benefits as well as associated social, economic and environmental benefits. Public health will be guaranteed if there is access to potable water and basic sanitation since the highest causes of illness and death in developing country is related to poor access to potable water and basic sanitation. As a result of this, illness and deaths reduce the productivity of the economy of a nation; poor sanitation has an adverse effect on the environment which in turn may affect the source of the economy like agriculture and tourism.

One of the most important benefits of water and sanitation improvements is the time saving associated with better access. Time savings occur as a result of the relocation of a well or borehole to a site closer to user communities, the installation of piped water supply to households, closer access to latrines and shorter waiting times at public latrines. These time savings translate into either increased production, improved education levels or more leisure time (Hutton & Haller, 2004).

WHO figures asserted that improved water supply reduces diarrhea morbidity by 6 percent to 25 percent, and improved sanitation reduces morbidity by 32 percent. Thus, the improvement in water supply and sanitation has a direct and concrete impact on health. As Hutton, *et al*, (2007) explain the occurrence of diarrheal diseases caused by unsafe drinking water and improper sanitation would be reduced if improvements were made in water and sanitation. Since diarrheal diseases are highly associated with unsafe drinking water and sanitation and poor hygiene, the improvements in water and sanitation would have a significant outcome.

The improvements in water supplies and sanitation also have an impact on poverty and the economy, as it is logical that only healthy people are strong enough to work and fulfill their needs. As Hutton, *et al*, (2007) stated the improvement of water and sanitation will have economic benefits of three types: direct economic benefits of avoiding diarrheal diseases, indirect economic benefits related to health improvements and non-health benefits related to improvements in water and sanitation. The direct economic benefits of avoiding diarrheal diseases include cost savings due to the reduced incidence of diarrheal disease, full health care costs, and non-health sector direct costs. The indirect economic benefits include productivity effects of improved health and the non-health benefits.

Table : The primary and economic impact, and its improvement

Improvement	Primary Impacts	Economic Impacts
Closer latrine access and improved latrine population ratio	<ul style="list-style-type: none"> • Less open defecation • Less latrine access time • Intangible user benefits • Improved health status due to less exposure to pathogens • Less user of public latrines 	<ul style="list-style-type: none"> • Saved health care costs • Improved aesthetics (visual effects and smells) • Increase school participation • Better living standards • Household incomes rise • Labor productivity • Value of saved lives

Sources: WSP-EPA, 2008

2.26. Water Quality Parameters

2.26.1. Physical- Chemical Quality of Drinking Water

Chemical contaminants in drinking-water may be categorized in various ways.

Table : Categorization of sources of chemicals in drinking water

Categorization of sources of chemicals in drinking water	
Sources	Examples
Naturally occurring chemicals	Rocks and soils, cyanobacteria in surface water
Chemical from agricultural activities including pesticides	Application of manure, fertilizers, and pesticides; intensive animal production practices
Chemical from human settlements	Sewage and waste disposal, urban runoff, fuel leakage
Chemical from industrial activities	Manufacturing, processing, and mining
Chemicals from water treatment and distributions	Water treatment chemicals; corrosion of and leaching from, storage tanks and pipes

Sources: WHO, chemical safety of drinking water,

2.27.1.1 Turbidity

Turbidity is a measure of the relative clarity or cloudiness of water. It is not a direct measure of suspended particles, but rather a general measure of the scattering and absorbing effect that suspended particles have on light (Health Canada, 2012).

Turbidity in water is caused by inorganic or organic matter or a combination of the two. Turbidity in surface waters may be the result of a particulate matter of many types and is more likely to include attached microorganisms that are a threat to health. Turbidity in the distribution systems can occur as a result of the disturbance of sediments and biofilms. But it is also from the ingress of dirty, water from outside the system (WHO, 2011, Lick, W. 2008). The recommended median turbidity should be below 0.1 Nephelometric Turbidity Unit (NTU) although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2004).

2.27.1.2. Hydrogen Ion Concentration (pH)

As stated by WHO (2004), Hydrogen Ion concentration (**pH**) is the main operational water quality parameter; although within typical ranges, it has no direct impact on consumers. Low pH levels can increase corrosive characteristics resulting in contamination of drinking-water and bad effects on its taste and appearance.

As reported by Karanth, (1987), various factors bring about changes the pH of water. The higher pH values observed suggests that carbon dioxide, carbonate, bicarbonate equilibrium is affected more due to change in Physicochemical condition.

According to WHO (2006), the P^H standard limit drinking water should be between 6.5-8.5.

2.27.1.3. Total Dissolved Solids

As stated by Murphy (2007a), total solids refer to the presence of materials suspended or dissolved in water and is related to both electrical conductivity and turbidity.

According to WHO (2003), total dissolved solids comprise inorganic salts and small amounts of organic matter that is dissolved in water. TDS in drinking-water originates

from natural sources, sewage, urban runoff and industrial wastewater. Concentrations above 500 ppm of TDS may cause adverse taste effects on drinking water.

2.27.1.4. Water Temperature

According to Volk *et al.*, (2002), in an analysis of the Physicochemical quality of pipe water samples, the temperature is considered as a critical parameter. It has an impact on many reactions, including the rate of disinfectant decay and by-product formation.

As reported by WHO (2004), the water temperature increases, there is an increase in the disinfectant demand and byproduct formation, nitrification, and microbial activity. It is desirable that the temperature of drinking water should not exceed 15°C because the palatability of water is enhanced by its coolness.

According to Mombal *et al.*, (2006), temperatures above 15°C can speed up the growth of nuisance organisms such as algae, which can intensify taste, odor, and color problems in drinking water.

2.27.1.5. Electrical Conductivity (EC)

Electrical Conductivity is the ability of a solution to conduct an electrical current is governed by the migration of solutions and is dependent on the nature and numbers of the ionic species in that solution. This property is called electrical conductivity. It is a useful tool to assess the purity of water. The permissible limit for electrical conductivity (EC) is 300 $\mu\text{S cm}^{-1}$ (Reda AH, 2016).

According to Lehtola *et al.*, (2002), conductivity increases with increasing amount of mobility of ions these ions, which come from the breakdown of compounds and conduct electricity because they are negatively or positively charged when dissolved in water.

As reported by Murphy, (2007), specific conductance is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution. With more ions in the water, the water's electrical conductivity (EC) increases.

According to Kegley and Andres, (1997), by measuring the water's electrical conductivity, one indirectly determines its TDS concentration.

2.27.1.6. Nitrates

As stated by Udaybir *et al.*, (2014), WHO, (2006), the presence of Nitrate in ground and surface water is because of agricultural activity it is one of the earliest chemicals to cause general concern among public health authorities and water suppliers. Its presence in drinking-water is associated with contamination by excessive use of fertilizers (both inorganic and organic), in combination with inappropriate farming practices and/or sewage. This chemical occurs widely throughout the world in both groundwater and surface water and presents a particular problem in shallow wells. Nitrate is a major problem for bottle-fed infants, in whom the risk of methemoglobinaemia (“blue-baby syndrome”) increases as the concentration of nitrate rises above 50 mg/L. The risk is increased by the presence of nitrite, which is a much more potent methemoglobinaemia agent than nitrate, and by the presence of microbial contamination, which can lead to gastric infections in infants.

2.26.1.7. Phosphate

According to Lehtola *et al.*; (2002), it is a natural element found in rocks, soils, and organic material. Its concentration in clean waters is generally very low. However, phosphorus is used extensively in fertilizer and other chemicals, so it can be found in higher concentrations in areas of human activity.

As stated by USEPA (1999), Phosphorus is generally found as phosphate (PO_4^{3-}). High levels of phosphate, along with nitrate, can overstimulate the growth of aquatic plants and algae, resulting in high dissolved oxygen consumption (Miettinen *et al.*, 1997; Lechevallier *et al.*, 1990). The primary sources of phosphates to surface water are detergents, fertilizers, and natural mineral deposits (Murphy, 2007).

Phosphate levels greater than 1.0 mg/l may interfere with coagulation in water treatment plants. As a result, organic particles that harbor microorganisms may not be completely removed before distributing the water to the users (Murphy, 2007b).

According to Miettinen *et al.*, (1997); Lehtola *et al.*, (2002), concentrations of phosphorus compounds in water are an indicator of contamination of water by human activity and draws significant influence in water quality management.

2.27.1.8. Fluoride

As reported by Fawell *et al.* (2006) and USNRC, (2006), elevated fluoride intakes can have more serious effects on skeletal tissues. Skeletal fibrosis (with adverse changes in bone structure) may be observed when drinking water contains 3–6 mg of fluoride per liter, particularly with high water consumption. Crippling skeletal fluorosis usually develops only where drinking-water contains over 10 mg of fluoride per liter. Traces of fluorides are present in many glasses of water, with higher concentrations often associated with ground waters. Fluoride is widely used in dental preparations to combat dental caries, particularly in areas of high sugar intake. In some countries, fluoride may also be added to table salt or drinking-water in order to provide protection against dental caries. The amounts added to drinking-water are such that final concentrations are usually between 0.5 and 1 mg/l. The fluoride in final water is always present as fluoride ions, whether from natural sources or from artificial fluoridation. The Ethiopian Rift Valley groundwater has very high fluoride levels, ranging from 0.4 to 36 mg-F/L. The water sources used in areas with the highest population densities have fluoride contents of 3.5 to 13.0 mg-F/L. Studies from other countries^{11,12} and our own experience in Ethiopia¹⁰ have shown that these levels cause dental fluorosis in children and over a prolonged period skeletal and crippling fluorosis (Frank *et al*; 2010).

In the Ethiopian Rift Valley dental mottling has been recognized in areas with fluoride concentrations in water as low as 2 mg-F/L. Higher levels, above 4 mg-F/L cause severe disfiguring dental fluorosis with enamel hypoplasia. Under the hot and dry conditions in the tropics, fluoride concentrations of 4 to 6 mg F/L in the drinking water (or daily fluoride absorption of more than 10 mg-F) may cause skeletal fluorosis with serious complaints in a substantial part of the population over the age of 45 years and in the Ethiopian Rift Valley, with fluoride levels above 4 mg-F/L, most of our patients developed neurological complications after 15 years of exposure. Concentration in drinking water may have to be lower than the WHO recommended 1.5 mg-F/L (Frank *et al*; 2010).

2.27.1.9. Iron

According to WHO (2003), Iron is one of the most abundant metals in earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/l. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is found in natural freshwaters and in some ground waters. High concentrations do give rise to consumer complaints because the iron discolors aerobic waters at concentrations above about 0.3 mg/l.

2.27.1.10. Manganese

As reported by WHO (2011), manganese is one of the most abundant metals in earth's crust, usually occurring with iron. Manganese is naturally occurring in many surface water and groundwater sources and the presence of manganese in drinking-water, like that of iron, may lead to the accumulation of deposits in the distribution system. Concentrations below 0.1 mg/l are usually acceptable to consumers. Even at a concentration of 0.2 mg/l, manganese will often form a coating on pipes, which may slough off as a black precipitate and the health-based guideline value is 0.4 mg/l.

2.27. Bacteriological Water Quality Parameters

Drinking water quality is becoming an issue of global human health concern, principally due to water contamination with pathogens. Thus, the government of Ethiopia was striving to enhance all national efforts towards the efficient, equitable and optimum utilization of water resources to access a universal coverage in drinking water (Tadesse *et al*; 2017).

It has a strong impact on people's health because water is a means of transmission for many pathogenic microorganisms that cause diarrheal diseases. In order to reduce disease outbreaks emanated from polluted water, it is important to emphasize on water quality management since the presence of certain microorganisms in water is used as an indicator of possible contamination and an index of water quality (WHO, 2004).

2.27.1. Coliform Bacteria

Total Coliforms are the ones that are commonly measured as indicator bacteria for drinking water quality (Brian, 2002; Hurst *et al.*, 2002). They are defined as aerobic and facultative anaerobic non-spore forming bacteria that ferment lactose at 35 to 37°C with the production of acid and gas within 24-48 hours (WHO, 1985; Hurst *et al.*, 2002). Coliform bacteria belong to the family Enterobacteriaceae and include *Escherichia coli* (E.coli) as well as various members of the genera Nitrobacteria, Klebsiella and Citrobacter (Hurst *et al.*, 2002). These bacteria originate in the intestinal tract of warm-blooded animals and can be found in their wastes. They can also be found in soil and on vegetation (Brian, 2002; Nold, 2008).

Although coliform bacteria are not pathogens, their presence indicates the possibility of finding pathogens in drinking water (Nold, 2008). Consequently, they are used to assess possible faecal contamination or water pollution from sewage. According to Hurst *et al.* (2002), the persistence of total coliform bacteria in aquatic systems is comparable to that of some of the waterborne bacterial pathogens. Furthermore, coliform bacteria are relatively simple to identify and are present in much larger numbers than more dangerous pathogens (Brain, 2002; Hurst *et al.*, 2002). For this reason, the degree of faecal pollution and the presumed existence of pathogens can be estimated by monitoring coliform bacteria (Volk *et al.*, 2002).

2.27.2. Faecal Coliforms (Thermo tolerant Bacteria)

Faecal coliforms live in the intestines of warm-blooded animals (Garcia-Armisen and Servais, 2006; Howarth, 1996). As a result, they show excellent positive correlation with faecal contamination of water from warm-blooded animals (Hurst *et al.*, 2002). According to Aliev *et al.*, (2006), thermotolerant bacteria are found in the subgroup of coliform bacteria that grow at 44°C.

Apart from the fact that the faecal coliform E.coli is considered as one indicator of faecal contamination of water (Stephen and Gundry, 2004), some strains such as enter hemorrhagic and enteroinvasive have become serious causative agents of emerging waterborne diarrheal disease (Nold, 2008). The presence of coliform bacteria in potable water indicates unsuitable sanitation practices (Howarth, 1996; Garcia-

Armisen and Servais, 2006). Such occurrences may be a result of poor water treatment systems, leakages in the pipelines, and or regrowth in the distribution system (Geldreich, 1996).

Table: Risk category and.....

Count per 100ml	Risky category
0	In conformity with WHO guidelines
1-10	Low risks
11-100	Intermediate risks
101-1000	High risks
>1000	Very High risks

Sources: IRC, 2002

2.28. Conventional Drinking Water Treatment

According to WHO, (2000), conventional treatment includes the following: pre-sedimentation or screening, chemical coagulation and flocculation, final settling or clarification, filtration, and disinfection. Many water treatment plants use a combination of coagulation, sedimentation, filtration, and disinfection to provide clean, safe drinking water to the public. All surface water and some ground waters require treatment prior to consumption to ensure that they do not represent a health risk to the user. Health risks to consumers from poor quality water can be due to microbiological, chemical, physical or radioactive contamination.

However, microbiological contamination is generally the most important to human health as this leads to infectious diseases which affect all population groups, many of which may cause epidemics and can be fatal (WHO, 2000).

Treatment processes usually function either through the physical removal of contaminants through filtration, settling (often aided by some form of chemical addition) or biological removal of microorganisms. It is usual for treatment to be in a number of stages, with initial pretreatment by settling or pre-filtration though coarse

media, sand filtration (rapid or slow) followed by chlorination; this process known as multiple barrier principles (WHO, 2004a). In water treatment plants, microbial pathogens, parasites, and chemical contaminants can be physically removed by processes such as coagulation, precipitation, filtration, and adsorption, or the pathogens and parasites can be inactivated by disinfection or by the high pH resulting from water softening (Bitton, 1999).

Microbial removal during water softening is due to the physical removal of microorganisms by adsorption to positively charged magnesium hydroxide flocs and microbial inactivation at detrimental high pH (≥ 11) (Bitton, 1999). According to WHO (2004), maximum removal possible in lime softening is 99% at pH 11.5 for 6 hours at 2 – 80°C for bacteria, 99.99% for viruses at pH >11 depending on the virus and on settling time, and 99% for protozoa through precipitate sedimentation and inactivation at pH 11.5. Most of the chemical contaminants can also be removed by the process of adsorption (WHO, 2008).

According to Bitton, (1999), inactivation of microorganisms in drinking water treatment performed with disinfectants. The most common disinfectant is chlorine. Chlorine is generally quite efficient in inactivating pathogenic and indicator bacteria. Water treatment with ≤ 1 mg/L of chlorine for about minutes is generally efficient in significantly reducing bacteria numbers and conventional drinking water treatment, one of the important processes is coagulation which is vital for the removal of all the physical, chemical and microbial contaminants that are found in the source water.

2.29.1. Coagulation for Drinking Water Treatment

Surface waters generally contain a wide variety of colloidal impurities that may cause the water to appear turbid or may impart color. Turbidity is most often caused by colloidal clay particles produced by soil erosion. Color may result from colloidal forms of iron and manganese or, more commonly, from organic compounds contributed by decaying vegetation. Colloidal particles that cause color and turbidity are difficult to separate from water because the particles will not settle by gravity and are so small that they pass through the pores of most common filtration media (Benefield *et al.*, 1982).

Colloidal suspensions are often stable for indefinite periods (Skoog et al., 1997). To be removed, the individual colloids must aggregate and grow in size. Aggregation is complicated not only by the small size of the particles but more importantly by the fact that physical and electrical forces keep the particles separated from each other and prevent the collisions that would be necessary for aggregation to occur (Benefield et al., 1982). Fortunately, the stability of most suspensions of this kind can be decreased by heating, by stirring and by adding electrolyte. These measures destroy the stabilizing forces and bind the individual colloidal particles together and give an amorphous mass that settles out of solution and is filterable. The process of converting a colloidal suspension into a filterable solid is called coagulation or agglomeration (Benefield et al., 1982; Skoog et al., 1997).

The production of potable water from most raw water sources usually entails the use of coagulation/flocculation stage to remove turbidity in the form of suspended and colloidal material. Coagulation has also remained the most widely practiced method of removing particulate and organic matter in wastewater treatment (Song et al., 2004; Prasad, 2008).

2.29. *Moringa stenopetala* Seed Powder for Water Treatment

Moringa is a multipurpose tree with considerable economic and social potential and its cultivation is currently being actively promoted in many developing countries. Seeds of this tropical tree contain water-soluble, positively charged proteins that act as an effective coagulant for water and wastewater treatment. This study evaluated the effectiveness of *Moringa oleifera* and *Moringa stenopetala* seed powder in water purification as a replacement coagulant. Water treatment with *M. stenopetala* was found to be more effective for water purification than treatment with *M. oleifera* seed. Indeed, it has been given little research and development attention. Unlike *M. oleifera*, little scientific research has been conducted on the properties and potential uses of *M. stenopetala* in general and its seeds in particular.

As reported by Mark, (1998). *Moringa stenopetala* belongs to family Moringaceae that is represented only by a single genus *Moringa*. The genus is represented by 14

species to which *Moringa stenopetala* belongs. Northeast tropical Africa is a center of endemism plus diversity to the genus.

According to Edwards et al. (2000), *Moringa stenopetala* is a tree 6-10m tall; trunk: more or less 60cm in diameter at breast height; crown: strongly branched sometimes with several branches; thick at base; bark: white to pale gray or silvery, smooth; wood: soft; Leaves: up to 55cm long; Inflorescence: pubescent, densely many-flowered panicles ca. 60cm long.

As reported by Ethiopian Tree Fund Foundation (2006), The habitat where the genus occur in Ethiopia as summarized from the herbarium sheets of the National herbarium includes rocky areas along rivers, dry scrubland, Acacia-Commiphora woodland, water courses with some evergreens, Open Acacia-Commiphora bushland on grey alluvial soil and in cultivation around the village. *Moringa stenopetala* is cultivated in terraced fields, gardens, and small towns. The species is found to grow in Keffa, Gamo Gofa, Bale, Sidamo, Borana and Debub Omo zones, and in Konso and Dherashe especial woredas.

According to Rams (1994), *Moringa stenopetala* is often referred to as the African Moringa Tree because it is native only to southern Ethiopia and northern Kenya. It is reported that the edible parts are exceptionally nutritious; the leaves are one of the best vegetable foods that can be found in the locality. All parts of the tree except the wood are edible, providing a highly nutritious food for both humans and animals. The flowers are a good nectar source for honey; can be eaten or used to make a tea and the seeds are rich oil sources for cooking and lubricant uses.

According to Jahn, (1984), many parts of the plant have been used in medicinal preparations. The wood is very soft; useful for paper but makes low-grade firewood and poor charcoal. Report from Gupta and Chaudhuri, (1992), revealed that very muddy water can be cleared when crushed seeds are added. Solid matter and some bacteria will coagulate and then sink to the bottom of a container.

As reported by Ethiopian Tree Fund Foundation (2006), *Moringa stenopetala* grows wild at elevations between 1,000 and 1,800 m (Mark, 1998) but it will grow as high as 2200m and as low as 300m (herbarium source) in Ethiopia. Optimum light for germination of all *Moringa* species is half shade.

Moringa stenopetala is commonly called shiferaw in Amharic, cabbage tree in English, and it has different names like shelagda, tallakata, haleko, alako in the various areas of Southern Ethiopia (Engels et al., 1991; Yalemtehay Mekonnen and Amare Gessesse, 1998). It is cultivated in the field and backyard within the villages in Konso (Engels et al., 1991) and in the different localities of Arbaminch, Negelle, and Wollayeta Sodo; almost every household has at least one or two *Moringa* plants in its compound (Yalemtehay Mekonnen and Amare Gessesse, 1998).

A wide range of physical and chemical processes are available for treatment of water. These methods include chemical coagulation using aluminum and ferric salts and cationic, electro-chemical precipitation, ultra filtration, ion exchange and reverse osmosis. However, it is not economically appealing because of high operational cost. Recently there has been increased interest in the subject of natural coagulants for treatment of water and wastewater in developing countries. Of these major interest the natural coagulants from tropical plants of the family of Moringaceae, which are *Moringa oleifera* and *Moringa stenopetala*, which can clarify turbid water (Jahn, 1981).

According to the study done by Getachew (2007) (unpublished), the medium fine particle of the seeds of *Moringa stenopetala* has shown an activity as a coagulant for the removal of water turbidity and 700 mg/L of the dose removes about 94% of the water turbidity of the water sample taken from Awassa Lake and 600 mg/L of the dose removes about 69% of water turbidity of the sample taken from Timbaho Monopol. On the other hand, due to the coagulation/flocculation process, 100% of the faecal coliform of both the water samples taken from Lake Awassa and Tembaho Monopol removed by the dose of 900 and 1000 mg/L of the seeds of *Moringa stenopetala*.

The medium fine powder of the seeds of *Moringa stenopetala* has also shown an activity on the removal of fluoride from water.

According to Getachew Redae (2007) unpublished, 900 mg/L of the seeds powder reduced the fluoride concentration of the water sample taken from Hawassa groundwater from 9.3 to 3 mg/L. The seeds of the other species, *Moringa oleifera*, have been shown to reduce fluoride levels from 20 mg/L to less than 1 mg/L in laboratory test (Stanely and Balasubramanian, 1999).

A study by Jahn (1986) reported that 100-150 mg/l of *Moringa stenopetala* was as effective in water clarification as 200 mg/l of *Moringa oleifera*. Earlier studies have shown that *Moringa stenopetala* has the capacity to remove lead from water (Mataka *et al.*, 2006). Furthermore, the studies showed that *Moringa stenopetala* is more effective in lead sorption from water than *Moringa oleifera*.

However, the problems of contamination of urban water distribution system are diverse. Wastes from improper sanitation (sewage) and agricultural and other activities make their way to the water distribution networks. Furthermore, break in the distribution system, inverse pumping of soil contaminants through interruption of the water supply, age and improper maintenance of the distribution system, low level of chlorine (treatment efficiency) usually compromise the integrity of the distribution system and quality of potable water (Muyina and Ngeakani, 1998; Phiri *et al.*, 2005). Similarly, underground water sources (hand-dug wells) from rural areas, and protected springs and hand-pumped wells positive for total Coliforms and faecal Coliforms (Mebratu, 2007).

Other findings were given conclusive evidence that water quality problems are rampant both with small-scale and large-scale water delivery systems in the country. This would pose high health risks to users unless prompt intervention is undertaken. This, therefore, necessitates the evaluation and putting in place of the sustainable monitoring system to determine the water quality status of municipal and rural water distribution systems.

Some drinking water treatment plant in developing countries faces a myriad of problems which are: large seasonal variation in raw water quality e.g. turbidity, the high cost of water treatment chemicals, underdosing of chemicals leading supply of poor drinking water. To overcome chemical coagulant problems it is necessary to increase the use of natural coagulants for drinking water treatment.

The need to treat water with natural coagulants became a common practice because the realization that the agencies burden with the responsibility of providing potable water to the public cannot cope with the present demand, this often leads to scarcity. This scarcity is often attributed to several reasons such as power failure, lack of chemicals, and breakdown in the operational system. Thus, the problem associated with this and its health implications are important (Jackson, 2003).

It has been described that the provision of adequate treated water to the majority of people in the developing countries such as Ethiopia is a goal, which must be achieved if there is need to be healthy at all time and at any time in the future. Treated drinking water now costs money, which may be sourced from a public supply, sachet packs, and bottled water. However, the methods of water treatment from biological materials by exploring the active agents of natural coagulants will indeed be cost-effective in providing water at a very cheap and affordable price and at all time in every household.

The biological treatment of water and other environmental pollutants is increasingly gaining popularity and acceptance. The techniques involved are cheap and do not need extensive training and controls. Coagulants from agricultural materials can minimize the limitations of using expensive and prohibitive cost for developing countries like Ethiopia by providing a less expensive means of flocculation and coagulation to obtain the appropriate degree of purification.

There is a current drive for maximum and optimum utilization of all the possible products from natural resources, of which, many new plant materials have already attracted attention. Various countries in the developing world are exploring the use of natural coagulants as an alternative to the commercially available coagulants; as issues related to water are the same, in many areas of the world, especially the

developing countries, attempt to provide water treatment alternatives is a current drive that everyone must exercise.

Though the initial water treatments by physical, chemical and thermal means were fast and controllable they require high energy and are cost prohibitive (Kaggwa, 2001). Use of natural coagulants, which can be readily propagated and easily accessible to common persons would offer a solution to our most water quality problem.

Various efforts are undergoing in several countries to solve water quality problems using natural coagulants, but such efforts are almost nonexistent or at their infancy stage in Ethiopia. Therefore, the objective of this study was to evaluate the possibility of *Moringa stenopetala* as an alternative coagulant in reducing turbidity, microbe's, fluoride and hardness. Further, the outcome of this will generally serve as a contribution to the knowledge of water treatment and may offer an alternative to the other methods of water treatment.

Use of natural coagulants for treatment of water and wastewater in developing countries is an area that is gaining interest. Tropical plants of the family of Moringa, are among some of the natural coagulants that have been studied for clarification of turbid water. Both *M. oleifera* and *M. stenopetala* is the most widely distributed, well-known and studied species of the family Moringaceae because of its previous economic importance as a source of the commercially important and more recently, as a multipurpose tree for arid lands and a source of water-purifying agents for developing countries (Morton, 1991).

The water-soluble Moringa seed proteins possess coagulating properties similar to those of alum and synthetic cationic polymers. The use of Moringa species for water clarification is a part of African indigenous knowledge. Jahn (1991) first studied and confirmed the coagulating properties of Moringa seeds after observing women in Sudan use the seeds to clarify the turbid Nile waters. *M. stenopetala* is less widely distributed than *M. oleifera* but *stenopetala* is reportedly more resistant to insect pests than other members of the family and its seeds are larger and easier to process than those of *oleifera* (Kayambazinthu, D., Forestry Research Institute of Malawi, personal communication). Although the water clarifying properties of *M. stenopetala* have not

been as extensively studied as those of *M. oleifera*, Jahn, Musnad, and Burgstaller (1986) cited as Seifu (2015) reported that 100–150 mg/L of *M. stenopetala* was as effective in water clarification as 200 mg/L of *M. oleifera* which indicates that *stenopetala* is more effective than *oleifera*. The mechanism of coagulation by *Moringa* is not well understood and different authors have attributed it to existence of proteins and non-protein flocculating agents (Gassenschmidt, Jany, Tauscher, & Niebergall, 1995; Ndabigengesere, Narasiah, & Talbot, 1995; Okuda et al., 2001)

2.30. Water Supply and Sanitation Policy in Ethiopia

According to MoWR (1999), The overall goals of the Federal Water Resources Management Policy (1999) and the Water Sector Strategy (2001) are to promote national efforts towards efficient, equitable and optimum utilization of the available water resources of Ethiopia in order to attain significant socioeconomic growth on a sustainable basis. Some of the major principles of the policy are devolving ownership to lower tiers and enhancing management autonomy to the lowest possible level, promoting involvement of all stakeholders, including the private sector; moving towards full cost recovery for urban water supply systems and recovery of operational and maintenance costs for rural schemes; and, enhancing urban water supply through autonomous bodies.

2.31. Sanitation Policy and Goals of Ethiopia

2.32.1. The Sanitation Vision for Ethiopia

Hundred percent implementation of improved (household and institutional) sanitation and hygiene by each community contributing to better health a safer, cleaner environment, and the socio-economic development of the country.

Objectives' of the policy:

- To protect and promote the health of the population and assure a friendly and healthy environment by controlling the environmental factors which are the direct and indirect cause for the spread of environmental health-related disease,
- To raise access to sustainable sanitation services.

- To enable all households to have access to and to use a sanitary latrine.
- To enable all institutions to have appropriate latrines with urinals and hand washing facilities are installed at schools, health posts, markets and public places.
- To construct communal latrines in peri-urban and urban slum areas, appropriate communal latrines are made available under community or private sector management.
- To effectively manage liquid waste systems by promoting reuse and recycling. In particular this covers organic matter and exploring and promoting biogas or ecological sanitation options.
- To safe drinking water supplies by routinely monitor for chemical and bacterial pollutants.

2.32. Challenges in Water Supply and Sanitation

According to Hunter, MacDonald and Carter (2010), a wide range of water problems faces nations and individuals around the world. These problems include international and regional disputes over water, water scarcity, contamination, unsustainable use of groundwater, ecological degradation, and the threat of climate change. High population growth rates, insufficient rates of capital investment, difficulties in appropriately developing local water resources, and the ineffectiveness of institutions mandated to manage water supplies (in urban areas) or to support community management (in rural areas) are contributing factors for the limited progress towards universal access to an adequate water supply. In short the key challenges of water supply and sanitation might be categorized under institutional, external drivers or local conditions.

Institutional challenges: According to UNEP/GRID-Arendal 2000, WHO/UNICEF (2011), RWSN (2008), one of the most significant challenges in the water sector is the apparent lack of reliable, up to date information on coverage, access and use of water. So, to maintain the gains already made; to push ahead quickly to provide drinking water and sanitation services to the billions of people living in rural areas; and to accelerate the successful efforts in urban areas to keep pace with the rising urban population, particularly by focusing on low income and disadvantaged groups basic documented information is necessary.

As reported by UNICEF & WHO, (2012), one of the major challenges in measuring safety, sustainability or consistency is the lack of adequate data. Most national monitoring systems do not collect information on these aspects. Where data do exist, they may not be nationally representative or may only cover certain settings. Moreover, non-operating systems, and intermittent or unreliable supplies, place an increased burden on the populations to health risks. The sustainability of improved drinking water sources is often compromised by a lack of technical skills, equipment or spare parts for operation.

According to RWSN, (2008), across rural Sub-Saharan Africa, in average 36% of hand pumps are non-operational more than 60% are non-operational.

As reported by Harvey (2008), the reasons for low levels of rural water supply sustainability are multifaceted and include limited demand, lack of affordability or acceptability among communities, limited sustainability of community management structures, inadequate supply chains for equipment and spare parts, insufficient government support, and environmental issues such as

External Challenges: According to WHO & UNICEF, (2013), a considerable funding gap to achieve full coverage; investment in developing sector capacity through strengthening institutional structures especially at regional, district and community levels. Lack of sustained financing mechanisms for recurrent costs coordination is also observed.

Population growth and urbanization: According to WHO/UNICEF, (2011), the world's population has been increasing mainly in developing countries. Some countries are failing to raise access to improved drinking water sources in line with population growth. The process of rapid urbanization presents challenges to increasing access to improved drinking water and the increase in informal settlements and poor environmental sanitation hinder efforts to increase access to safe drinking water in urban areas.

Climate Change: As reported by UNESCO, (2009), the most important impacts of climate change on humans and the environment occur through water. Climate change is likely to lead to increased water stress, meaning that drinking water necessities will

face increasing demand from competing uses of water such as agriculture and industry. An increased prevalence of severe weather events and climate-related natural disasters could result in an increased loss of functioning drinking water and sanitary facility infrastructures.

Social disparities: According to WHO (2010). The gap between the richest and poorest in the use of drinking water sources differs significantly by region and country. Access to improved drinking water sources increases with wealth, and access to piped water on premises is much higher among the richest and Some report indicates that almost two-thirds of total official development assistance for drinking water and sanitation is targeted to the development of large systems for urban systems than the rural one.

As stated by Gleick (2002), even though a lot of money has been spent on centralized, large-scale water systems it cannot be built or maintained with local expertise or resources. Traditional and community-scale water systems have been inadequately funded and supported.

According to WHO/UNICEF (2011), the pressure on water resources is growing due to the combined effects of population growth, urbanization, economic development and climate change. This also threatens the sustainability of water supplies. The region's most vulnerable to domestic water shortages include those where access to water is already limited, the population is growing rapidly, urban centers are spreading, and the economy is burdened by financial problems and a lack of skilled workers.

In the provision of adequate clean water and sanitation facilities to urban dwellers, the world faced many challenges, which are related to the capacity of the nations, (i.e. technological know-how and institutional), inadequate finance, rapid urbanization and declining of the global water resource.

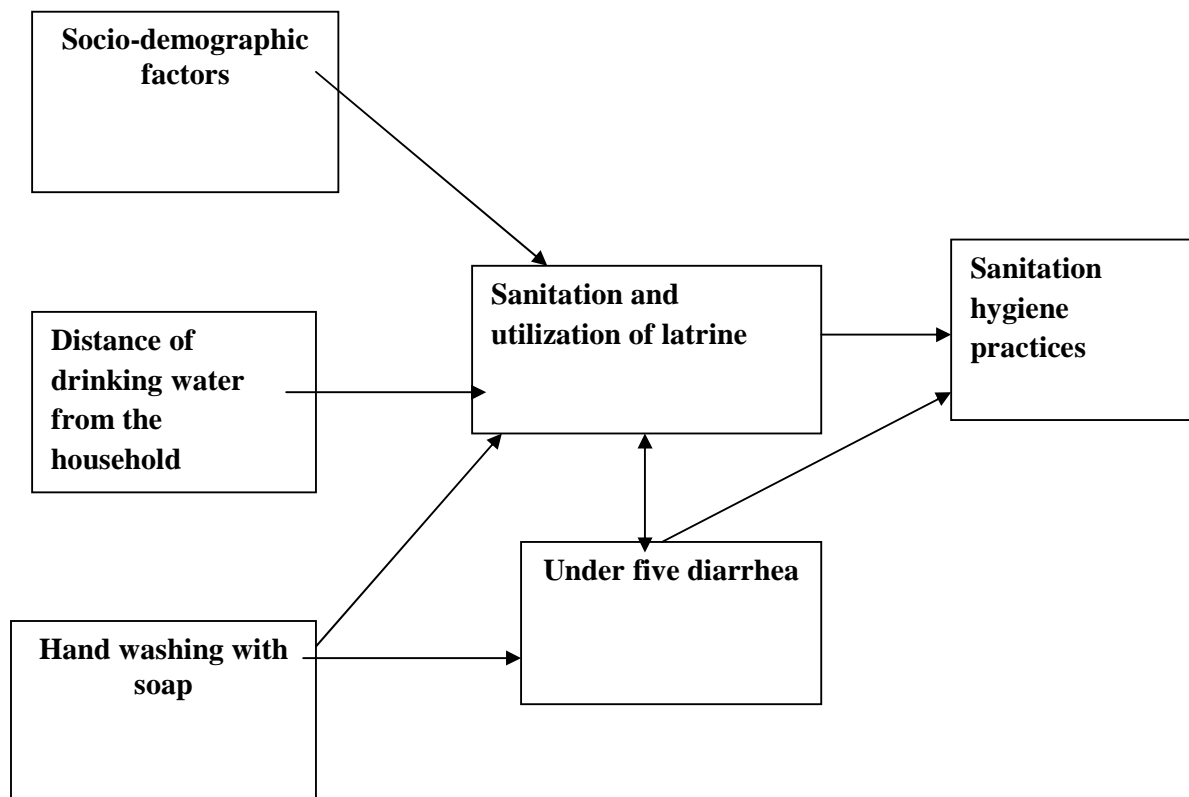


Figure 22: Conceptual framework Sanitation-Hygiene Practices of consumers

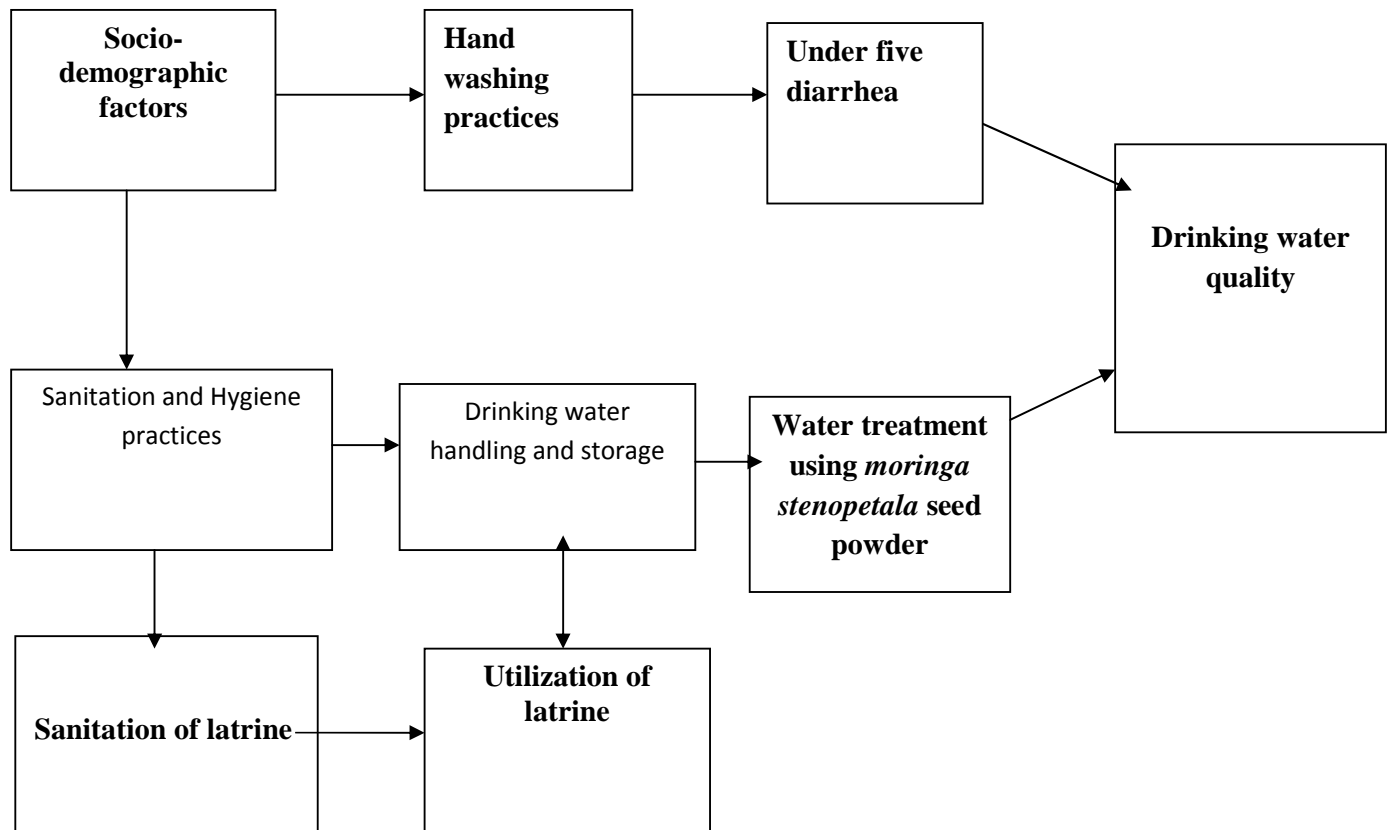


Figure 23: Conceptual framework of factors affecting drinking water quality and purification using *moringa stenopetala* seed powder

Chapter 3: The Research Design and Methods

3.1. Study Area and Period

The study was conducted in Bale-Robe and Ginnir towns of Bale Zone, Oromia Regional State Southeast Ethiopia, from June 2012 to August 2013. Bale-Robe town is one of the recently growing towns in Oromia Regional State located at 430 kilometers away from the capital of Ethiopia to southeast direction. The total population of Robe town was estimated to 59,355 with total households of 11,871. The town has a moderately highland climate with average minimum and maximum temperature of 9.42°C and 21.16°C, respectively. The annual rainfall of the town ranges from 535 mm and 1018 mm (R). The climate is seemingly conducive to the survival and development of parasites. The town of Robe is the capital of Bale Zone and one of the study area which draws three springs: Oda, Werabu and Kasso Shekmira for water sources in addition to the recently established groundwater boreholes.

Ginnir town is found in Bale Zone of Oromia regional state. There are two kebele and 13 developmental zones in the town; the town is located in the southeast of Ethiopia and 545 km from the capital city and 120 kilometers away from the capital of the Bale Zone - Robe town to the East direction. Ginnir woreda has a bimodal rainy season from March to May and from September to October; the town falls under Wenadega agro-climatic zone with an average annual minimum rainfall of 750mm and 1280.3mm.as a result, it has a moderate temperature. The total population of Ginnir town was estimated to be 37,021 with total households of 7,404. Ginnir is bordered on the south by the Weyib River which separates it from Goro woreda, on the west by Sinanana Dinsho, on the northwest by Gasera and Gololcha woreda, on the northeast by Seweyna, and on the east by Raytu woredas. Ginnir Town draws its water sources from two springs (Tsebel one and Tsebel two) that caped together.

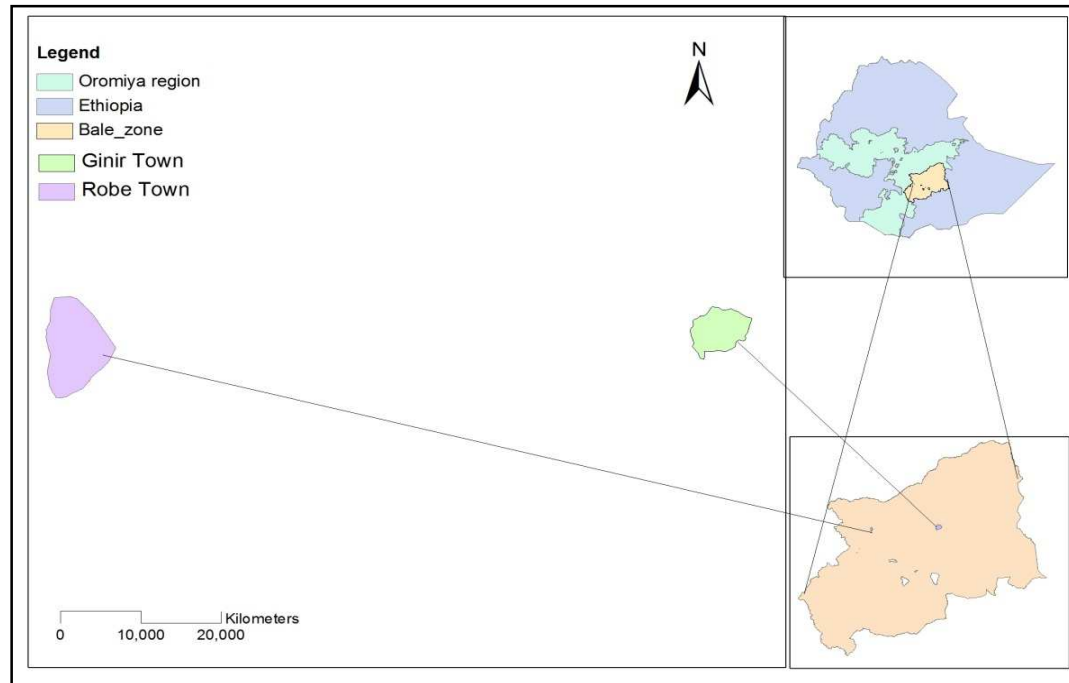


Figure 24: Location map of the study towns

3.2. Research Method

A mixed research paradigm comprises of quantitative and experimental research method has been used in this study. This paradigm was chosen because it was intended to measure the magnitude of sanitation and hygiene problems and optimize actions to be prioritized in the prevention of environmental sanitation and hygiene-related diseases.

Quantitative research is used to assess environmental sanitation and hygiene practices of consumers in the study area. An in-depth interview with key informants from both Robe and Ginnir towns was conducted to make the finding more comprehensive.

Experimental paradigm was used to evaluate the removal efficiency of *Moringa stenopetala* seed for turbidity, nitrate, and coliforms in drinking water.

3.3. Research design

A Community-based cross-sectional survey was conducted in Robe and Ginnir Towns.

3.4. Sample Size Determination and Sampling Procedures

For the quantitative part sample size was determined using single population proportion formula with the level of confidence of the study 95% ($Z_{\alpha/2} = 1.96$), the margin of error (D^2) 5%, p, the proportion of household practicing sanitation and personal hygiene to be 50% to get the maximum sample size.

$$N = \frac{(Z_{\alpha/2})^2 P (1-P)}{D^2}$$

$N = (1.96)^2(0.5) (0.5)/ (0.05)^2 = 384$, by considering 10% non-response contingency, then the final sample size became 422.

3.5. Study Variables

Dependent variables:

Water quality

Environmental Sanitation-Hygiene Practices

Independent variables: Socio-demographic and economic data: income, educational status, sex, religion, distance of drinking water from the household; water handling practices: main source of water used for drinking purpose, type container used for water collection and storage, water utensils' handling condition, utilization of latrine, sanitation of the latrine, hand washing with soap, under five diarrhea and latrine utilization, *Moringa Stenopetala* seed as alternative for water treatment.

3.6. Data Quality Control

For the quantitative survey quality of data was assured through the following methods; Using standardized adapted questionnaire from World Health Organization (WHO, 1994).

The questionnaire was translated into the local language (Afaan Oromo) and re-translated to the English language to check its consistencies by the language experts.

The data collection tools were pre-tested and necessary correction was made after the pre-test to reach a common understanding prior to the study

Data were collected by trained data collectors under the supervision of the supervisors after two days training was given for the data collectors and supervisors on the objectives of the study, sources of bias, observation and interview techniques.

The questionnaire was checked for completeness on daily basis by immediate supervisors. Each questionnaire was manually cleaned up for completeness, missed values and inconsistent of responses. The data were entered by trained data entry clerk and ten percent of the entered data was checked by the principal investigator for its correctness.

3.7. Sampling Procedures and Data Collection Methods

Household Interview, Sanitary Inspection, and Observation

The total sample size of the quantitative study was divided proportionally according to the number of households in the selected towns of Bale Zone. Study households were identified using systematic random sampling method of every 30 households for both Robe town and Ginnir Town.

The head of the household was the study unit for this study. If there were no mother or head of the household at the time of the survey, preferably the female daughter was selected to provide information since they have main responsibility in water and sanitation.

Sanitary inspection was conducted during a household interview regarding the covering of water storage vessels, water container volume, the presence of soap in the house, availability of hand washing facility, water, and detergent near latrines, cleanliness of latrines, availability of pamphlet on hygiene were collected using a checklist.

Observation checklist was used to assess the sanitary condition of selected water sources. The following items were included in the checklist: the physical status of protection box, the situation of the outlet and overflow pipe the drainage system and the general sanitation of the springs. WHO standard protected spring evaluation

checklist which has a score of the risk out of ten (9-10=very high risk, 6-8=high risk, 3-5= intermediate risk, and 0-2=low risk) was used to categorize them accordingly .

3.8. In-Depth Interview

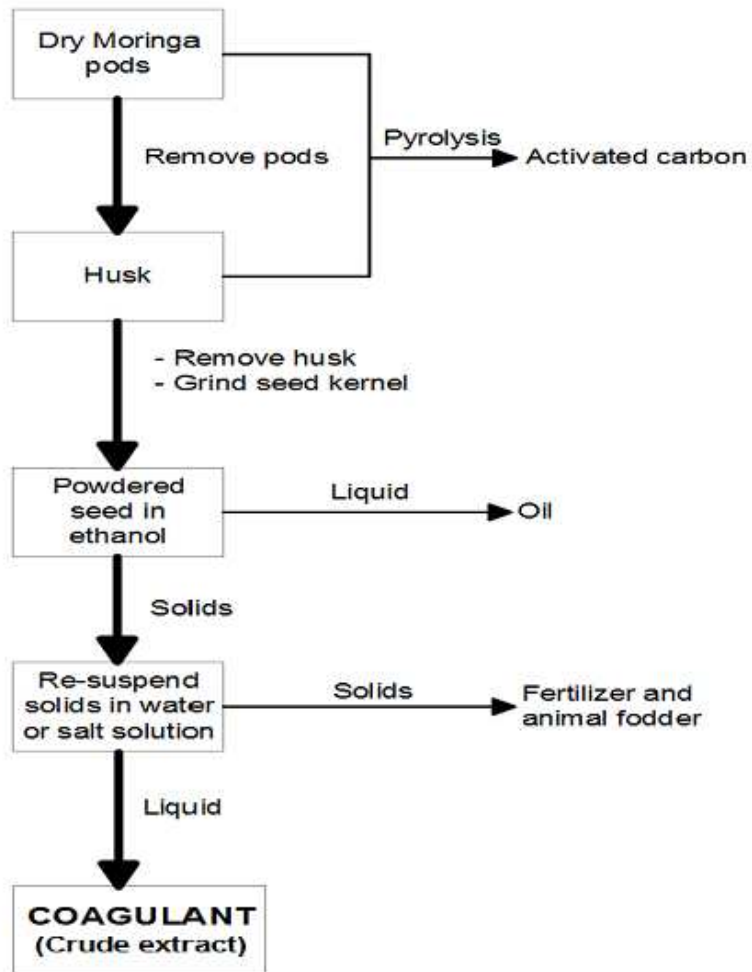
The qualitatively in-depth interview was conducted with municipality officials, water, and sanitation technical persons and community representatives using interview guidelines.

The key informants for this study were 12 people based on information richness of the study participants on water supply, quality, sanitation and hygiene-related problems of the Robe and Ginnir Towns. The study participants include 4 technical personnel's from water supply and sanitation office from each town, 1 participant from each town administration and sanitation facility office and 1 elder from each town.

A pair of Bachelor degree level data collectors, able to speak the local language were involved to carry out the in-depth interviews. Notes were taken and an audiotape recorder was used to prevent loss of information.

3.9. Collection and Preparation of the Seeds of *Moringa Stenopetala*

The dry pods of *Moringa stenopetala* were collected from the study area, Bale Zone of Southeast Ethiopia (Fig 24). The pods and wings were removed from the kernel manually and seeds were dried in an oven for 24 hours at 40°C to remove moisture in order to ease grinding. Then dry kernels were grinded into a medium-fine powder using Mortar and pestle. The *Moringa stenopetala* used in this study was obtained from Bale Zone Goro Wreda Perlis and the extraction method was based on the modified procedure developed by Okuda *et al.* (1999). A qualified seeds were selected and dried in an oven at 40°C for 24 h. The kernel was separated from hulls and wings and grinded to fine powder by using domestic blender.



Typical extraction of the coagulant component from moringa stenopetala seeds.

Then the powder of *Moringa Stenopetala* was measured using analytical balance at concentrations of 25mg/l, 50mg/l, 75mg/l, 100mg/l, 100mg/l, 150mg/l and 200mg/l.



Figure 25: *Moringa stenopetala* tree in the study area and the seed

3.10. Water Sample Collection and Analysis

A total of 71 water samples from the sources, households, and reservoirs were collected from Robe and Ginnir town during the study period. The physicochemical and bacteriological water quality analyses were done in Addis Ababa Environmental protection and Oromia water and Energy laboratories.

Samples for analysis were collected in accordance with the standard method of American Public Health Association APHA (1998).

Triplicate water samples were collected from each selected source of water from the respective towns. For the bacteriological analysis, water samples were collected in sterile glass bottles and transported to the laboratory in ice box containing ice freezer packs. From each sampling point, 300 ml samples were taken for analyses. For the chlorinated water samples, sodium thiosulphate was added to stop the chlorination process during transportation. Three milliliters (3ml) sodium thiosulphate were added into each sampling bottle and sterilized in the autoclave for 15 minutes at about 121°C. One hundred milliliters of a water sample for each test was filtered through a sterile cellulose membrane filter with a pore size of 0.45µm to retain the indicator bacteria. The filtration apparatus were sterilized before use and re-sterilized between samples using methanol when analyzing water samples (OXFAM, 2004). The cellulose

membrane filter was transferred from filtration apparatus to a sterilized aluminum petri-dish containing absorbent pad soaked with membrane lauryl sulfate tryptose broth (Wagtech, England) for total coliforms(TC) and fecal coliform(FC). For the determination of total coliform and fecal coliform, incubation was carried out at 37⁰C and 44⁰C, respectively.

With regard to the physicochemical analysis, 200ml glass water samples were collected, labeled and transported to the laboratory in the icebox. Except for nitrate and phosphate, all physicochemical parameters were analyzed at the site. Temperature and pH were analyzed using portable digital pH meter (Jenway model- 370, England). The pH meter was calibrated just before analysis using pH 4.0 and pH 7.0 and it was rinsed with distilled water from one sample to the other following the Jenway pH meter operation manual (Jenway,2003).

Total dissolved solids (TDS) and electrical conductivity were analyzed using portable digital conductivity meter (CC-401, Poland). Turbidity was analyzed using portable microprocessor turbidity meter (H193703 ELE international, Hungary). Nitrate and phosphate were measured using HACH DR/2010 spectrophotometer following HACH instructions (HACH, 1999). Copper, iron, calcium, and magnesium were analyzed using flame atomic absorption spectrophotometer. The Total hardness (T-H), Calcium hardness (Ca-H), Magnesium hardness (Mg-H) has measured titrimetrically by using EDTA.

Hardness and fluoride analyses: After treating the samples for 2 hrs using coagulant doses (100, 200, 300, 400, 500, 600, 700, 800, 900 mg/l) in 500 ml capacity graduated cylinders; hardness and fluoride were determined using plain test photometer method using Plain test tablets. Calcium, magnesium, and fluoride were determined at wavelengths of 570 nm, 520 nm, and 570 nm, respectively (*ELE International, 2003*). Total hardness was calculated using results of calcium and magnesium.

3.11. Multivariable Logistic Regression

The multivariable logistic regression for this study was binary multivariable logistic regression which is important to identify the factors that can affect the under-five

diarrhea; and it is a regression method commonly used when the outcome variable “**Y**” is binary or dichotomous and two or more predictor variables “**X_s**”, the equation to determine the probability or likelihood that under-five diarrhea has the condition ($y = 1$) that depends on the independent variable x_s is as follows:

$$\ln\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \dots, \text{ where } \alpha \text{ is a constant and } \beta \text{ is coefficient and } p$$

= probability of having the event “**y**”, i.e. the proportion of under-five diarrhea with $y=1$.

Before passing to the full model, It is checked that the bivariate logistic regression between Under-five diarrhea and the Independent variables. Therefore, the Independent variables which had a P-value of less than 0.25 in the Logistic regression were included in the full model.

3.12. Ethical Considerations

Ethical clearance was secured from Oromia Water and Energy Bureau. Letter of permission was obtained from Bale Water and Energy Department. A full explanation was provided to each respondent in the study. Respondents were provided with the letter of introduction written by the supervisor of study before they were interviewed. Respondents were informed about the purpose of study along with their right not to take part in the study without having to explain why. Each participant took part in the study willingly, and there were no objections. Participants of the study were informed that their responses to questions would be kept confidentially. Ethical clearance was secured from, UNISA, Oromia Water and Energy Bureau. Letter of permission was taken from Bale Zone Water and Energy Department and respective towns to collect the water samples for analysis.

3.13. Dissemination of Results

The study result will be disseminated by preparing seminars and reports to the respective organization (Robe and Ginnir Towns Health office and Water and Energy Resource Offices) and other Governmental and nongovernmental organization which are responsible for intervention.

Chapter 4: Results

4.1. Sanitation-Hygiene Practices and childhood diarrhea among households in Robe and Ginnir town of Bale Zone Oromia Regional state South East Ethiopia

4.1.1. Socio-demographic characteristics of study subjects

A total of 401 households out of 422, who have participated in this study were interviewed making a response rate of 95.02%. The majority 145 (36.2%) of the respondents were in the age range of 25-34 years. Concerning the educational status of the respondents 117 (29.2%) of them could not read and write (illiterate) and 205 (52.4%) of the respondents received a formal education. The mean family size of the households, 128(31.9%) had a family size of above seven. About 177(44.1%) were Muslim in religion followed by Orthodox Christians which was 177 (44.1%). About 312 (77.8%) had a monthly income of Less than 1000 ETB while 312(77.8%) had an income of less than 500ETB (Table 10).

Table 10: Socio-demographic characteristics of respondents, Robe and Ginnir town, December, 2013. (n=401)

Variables	Categories	Number	Percent
Age of respondents	15-24	138	34.4
	25-34	145	36.2
	35-44	68	17
	>44	50	12.5
Sex	Male	140	34.9
	Female	261	65.1
Educational status	Illiterate	117	29.2
	Read and write	76	19
	Primary education	60	15
	Secondary and above	148	36.9
Occupational status	Governmental employee	71	17.7
	Farmer	83	20.7

	Merchant	72	18
	Housewife	175	43.6
Monthly Income	<= 500Birr	312	77.8
	501- 1000 Birr	63	15.7
	>1000	26	6.5
Family size	1-3	65	16.2
	4-6	208	51.9
	>=7	128	31.9

4.1. 2. Water handling practices related to collection and transportation

About 152(37.9%) of respondents were found to use pipe water, 122(30.4%) were used water from protected spring and 33(8.2%) of them were collect water from the tanker and 7(1.7%) of them collected water from the surface source waters.

About 223(55.6%) reported that the time required to collect water was about 1-10minutes, 171(42.6) require 11 to 50 minutes, and 7(1.7%) reported about one hour to collect the water.

This study revealed that the most commonly preferred type of water collection container was Jerrican, which was 370(92.3%) followed by clay pots 25 (6.2%). From the total respondents, only 293(73.1%) of the respondents have reported cleaning of the water before water collection. In addition, the majority of the respondents were covering the collection container during transportation which was about 336(83.8%) of the respondents reported that they were covered the water containers during water transportation (Table 11).

The current study also revealed that 187(46.6%) of respondents collected water every other day, 161(40.1%) every day, 46(11.5%) twice a day. The housewife was highly responsive to collect water followed by children 58(14.5%) and housemaid 55(13.7%) from a source (Table 11).

Table 11. : Water handling practices related to collection and transportation in Robe and Ginnir towns of Bale Zone, South East Ethiopia, 2012

Variables	Frequency	Percent
Sources of water		
Protected spring	122	30.4
Unprotected spring	86	21.4
Rainwater	1	0.2
Tanker trunk	33	8.2
Surface water	7	1.7
Tap water	152	37.9
Time required to fetch water		
1-10 minutes	223	55.6
11-50 minutes	171	42.6
1 hour	7	1.7
Types of collection containers		
Clay Pot	26	6.5
Jerrican	375	93.5
Cover during transportation		
Yes	336	83.8
No	65	16.2
Container rinsing before collection		
Yes	293	73.1
No	108	26.9
Responsible body for water collection	263	65.6
Housewife	58	14.5
Children	55	13.7
Housemaid	25	6.2
Others*		
Interval of water collection		
Every other day	187	46.6
Every day	161	40.1
Twice a day	46	11.5
Others	7	1.7

**neighbors and Husband*

4.1.3. Water handling practices related to storage and usage by households

Two hundred thirty (57.4%) of the households preferred Jerrycans, 69(17.2%) plastic bucket, 15(3.7%) clay pots and 72(17.9%) prefer other materials for water storage. About 280(69.8%) were washed storage containers before refilling while 121(30.2%) did not. Likewise, 325(81%) households used separate containers with covering materials during water storage.

Pertaining to the way that the respondents' withdraw water from containers, 261(65.1%) of the households used pouring methods, 140(34.9%) used dipping methods. About 186(47.1%) of the households put water drawing utensils on table or shelf, 84(21.3%) inside the storage containers, 44(11.1%) on storage cover, 75(19%) put on the floor.

According to the observation during the data collection, the sanitation of the area near the storage containers was good in 260(64.8%) and poor in 141(36.2%) households. Regarding the possibility of animals to reach water storage containers was in about 148(36.9) households.(Table 12).

Table 12: Water handling practices related to storage and usage by households of Robe and Ginnir towns of Bale Zone, South East Ethiopia, 2012

Variables	Frequency	Percent
Type of storage containers		
Clay Pots	15	3.7
Jerrycan	230	57.4
Plastic bucket	69	17.2
Metal bucket	15	3.7
Barrel	72	17.9
Washing of container before refilling		
Yes	280	69.8
No	121	30.2

Cover of the storage containers			
Yes	325	81	
No	76	19	
Sanitation of the storage areas			
Yes	260	64.8	
No	141	36.2	
Possibility of animals			
contamination	148	36.9	
Yes	253	63.1	
No			
Methods of withdrawal from storage container			
Pouring	261	65.1	
Dipping	140	34.9	
Where water drawing utensils put			
Table or shelf	186	47.1	
Inside the container	84	21.3	
Storage cover	44	11.1	
Hang on well	3	0.8	
Floor	75	19	
Others	3	0.8	
Use cup for other purposes			
Yes	239	59.6	
No	162	40.4	

4.1.4. Sanitary Conditions of the Six Protected Springs

An observation check-list was prepared to evaluate the sanitary conditions of selected water sources in the study area. WHO prepared a standard protected spring evaluation checklist which has a score of the risk out of ten (9-10=very high risk, 6-8=high risk, 3-5= intermediate risk, and 0-2=low risk) (8). The following were included in the checklist: the physical status of protection box, the situation of out let and overflow pipe the drainage system and the general sanitation of the springs. Accordingly, the

study revealed that; Tesebele I(spring) and Testable II springs were found to have very high and high sanitary risk score respectively.

The most significant defects observed were inadequate protection, the absence of surface water diversion ditch, unsanitary overflow pipe and cover, lack of fencing, open for surface water contamination and poor drainage system.

Oda, Madda, Werabo and Kasoshekmera springs were graded as an intermediate level of risk. Some of the defects observed around these springs were: in sanitary, overflow pipe, lack of surface water diversion ditch, lack of fencing and also open for contamination (Table 13).

Table 13: Sanitary condition of six protected springs found in Robe and Ginnir Towns of Bale Zone in 2013

Spring site	*Sanitary risk score	Risk of contamination
Tsebele I- Ginnir	8	High risk
Tsebele II- Ginnir	8	High risk
Oda Spring-Robe	7	Intermediate risk
Madda Spring-Robe	8	High risk
Werabo Spring-Robe	7	Intermediate risk
Kasoshekmera Spring-Robe	8	High risk

* WHO guideline for drinking water quality, Vol. III.

4.1.5. Practices Related to Waste Management [Excreta] at Robe and Ginnir Towns

This study found that two hundred seventy (67.3%) of the study subjects had pit latrine at the household level. Regarding its utilization, 239 (88.5%) used the latrine frequently, 30 (11.1%) were sometimes and 1 (0.4%) never used at all. Concerning the sanitation of the latrine, only 137 (50.4%) was found in a good condition (Table 14).

One hundred twelve (84.8%) of the respondents who had no latrine at the household level, usually practiced defecation on open field and the rest 18 (13.6%) used their

farm fields for defecation. The main reasons for not having latrine are high cost/lack of money for 108 (84.4%) and lack of space for 20 (15%) for latrine construction.

Regarding the solid waste management practices of the respondents' majority, 193 (48.1%) disposed of their solid wastes (mostly garbage) in their pit, followed by 117 (29.2%) who were burning it as a solid waste management practices.

Domestic waste, when sorted, recycled well or composted, can be turned into a resource but it was found that the greater part of waste generated generally did not undergo such process before the final disposal. The study result indicated that only 9 (2.2 %) of the sampled households had used waste as manure (compost) for home gardening.

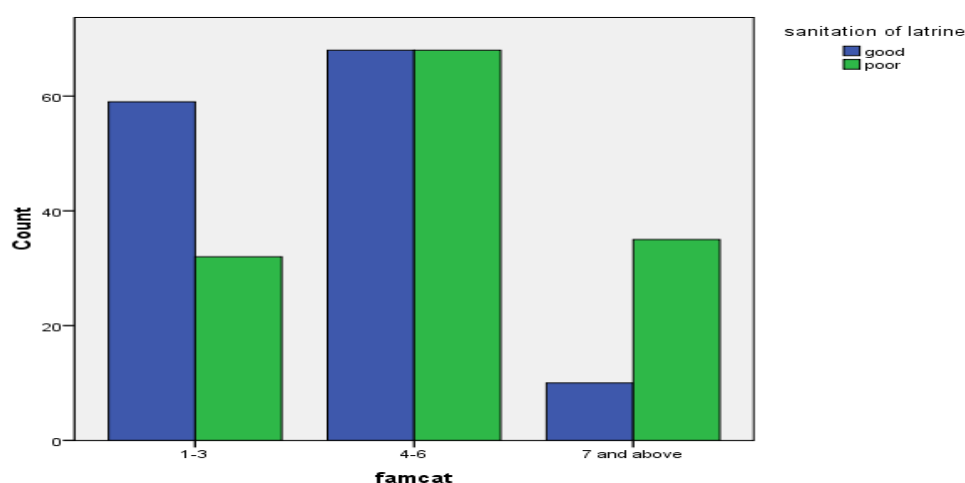
Concerning personal hygiene; the majority 210 (52.4%) of the respondents took shower every week. The place for bathing took place; most of the respondents took baths in the bucket in their own houses and others in their own bath which accounted 226(56.4%) and 62(15.5%) respectively (Table 15).

Table 14: Practices related to liquid and solid waste management and personal hygiene in Robe and Ginnir town, December 2013 (n=401)

Variables	Response categories	Number	Percent
Latrine availability	Yes	270	67.3
	No	131	32.7
Type of latrine	Pit latrine	269	99.6
	VIP	1	0.2
Latrine utilization	Always	239	88.5
	Sometimes	30	11.1
	Never at all	1	0.4
Sanitation of the latrine	Good	137	50.4
	Poor	135	49.6
If latrine where unavailable for defecation	Open field	112	84.8
	Farmland	18	13.6
	Communal	2	1.5
Distances of water source from	1-10 meter	136	50.4

latrine	>10 meter	134	49.6
	using coved materials	62	25.7
How the refuse is stored	using uncovered material	187	46.6
	Pit	98	24.4
	Others	13	3.2
refuse stored in the home	Yes	226	56.5
	No	174	56.5
Hand washing practice after latrine usage	Yes	194	71.9
	No	76	29.1

Among the households that had children, 125 (47.3 %) thrown waste into the garbage, 88 (33.3 %) left it out in the open field and 44 (16.7 %) buried children's stool. Only 7 (2.7%) of households, the children's stools were contained the children's stool and dropped into toilet facility.



“Famcat” indicates family size category

Figure 26: Distribution of sanitation of latrine by family household size In Ginnir and Robe town

This study found that as family size increase, the perceived quality/sanity of the Latrine decreases (Fig.22).

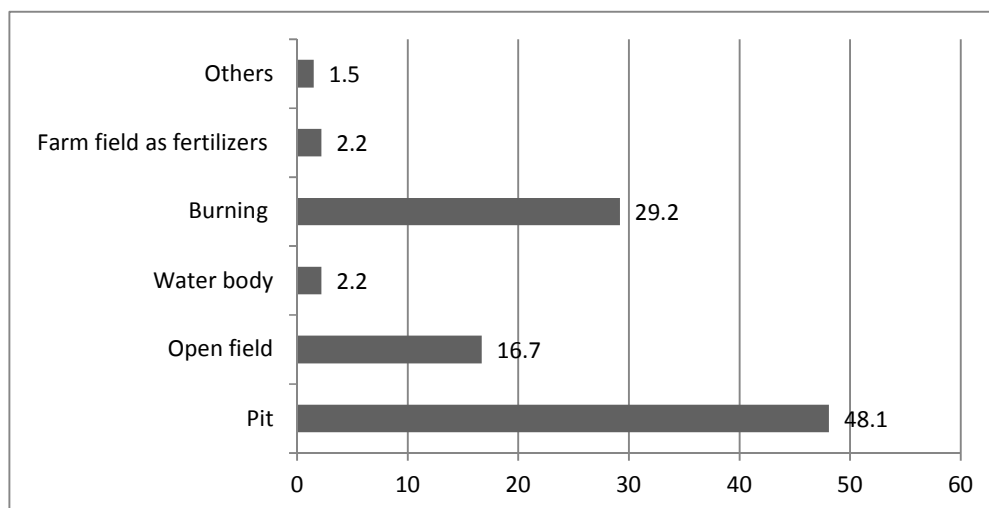


Figure 27: Solid Waste Management system at household level at the study area

Regarding the solid waste management in the study area, about 29.2% burnt the waste, 48% put it in the pit; about 17% throw the waste in open fields (Fig.23).

4.1.6. Personal Hygiene Practices

The majority 347 (86.5%) of the households had soap in their houses on the day of the interview which indicates the availability of higher percentage of soap in the households. The majority of respondents 347 (86.5%) reported using soap for washing during the interview day or a day before the interview.

Respondents were asked for what purpose they have used soap during the interview day or a day before the interview. The main reasons mentioned by the respondents were for washing their hands 349 (87%), washing of clothes 157 (39.2 %), washing of body 327 (81.5%), washing their children's body 104 (25.9 %) and washing their children's hand 108 (26.9%). Those households that mentioned they have washed their hands with soap, they were asked the occasions of hand washing performed. A large majority of the households 351 (87.5 %) had reported they washed their hands before eating food. It is essential to note that 253 (63.1%) of the respondents indicated that they washed their hands with soap after visiting toilet facility. Other responses mentioned by households were after eating food 351 (87.5%), before preparing food 217 (54.1%), before feeding children 65 (16.2%) and after cleaning children's bottom 88(21.9%).

Only about 9.2 % of the respondents indicate that they are ‘satisfied’ or ‘highly satisfied’ by the water which is available to their household. The mean estimated distance to the water sources is reported to be 24.97 meters far from the households with a standard deviation of 107.29 meters.

In this study, among the total households surveyed, about 22.4% had provided labor useful for site clearing and construction, 9.5% had provided cash in response to the project cost would be covered by the community, 5.7% had provided local materials such as wood for the construction of the water sources and fencing, and only 2.2% had been involved in active decision making processes such as in site selection, financial and project management issues.

Diarrhea prevalence is highest among children less than five years old in the study area. If there were diarrhea or not in the last two weeks before data collection were assessed. Among the households which were interviewed 201 (50.1%) reported there was diarrhea in the last two weeks preceding the survey. The study shows that among households which had diarrhea, 194 (96.5%) were children under age five years have had diarrhea, and 111 (55.2%) were one to two years old, 83 (41.3%) were two to five years old, while only 7(3.5%) were the age group greater than five years old who had diarrhea in the two-week period before the survey.

All respondents were asked pertaining to their knowledge about the critical or the most important times for washing hands. The households were spontaneously reported that hand washing before eating food 133 (33.2%), after defecation 49 (12.2 %) and after eating food 132 (32.9%) was important. Only 105 (26.2 %) of households mentioned before food preparation, 32 (8 %) mentioned before and after feeding children and only 39 (9.7%) households cited after cleaning children’s bottom(perennial area).

4.1.7. Factors Associated With the Presence of Childhood Diarrhea

Among the variables with which the associations were done; latrines availability, occupational status, family size, sanitation of the latrine, sanitation of the water storage area and were households without latrine used were significantly associated

with the presence of diarrheal diseases in the study area. The results concerning selected environmental sanitation variables (sanitation of the latrine, sanitation of the water storage area and were households without latrine used) and the presence of diarrhea in the last two weeks were having an association.

The results indicate that sanitation of the latrine was significantly associated with the presence of diarrhea in the last two weeks 7.215 ($p=0.007$). In addition, there was a statistically significant relationship between family size and the presence of diarrhea in the last two weeks 34.764 ($p=0.000$). There was a statistically significant association between latrines availability and the presence of diarrhea in the last two weeks ($X^2=25.440$; $p=0.000$). There is also a statistically significant association between occupational status and the presence of diarrhea in the last two weeks ($X^2=12.785$; $p=0.005$). The risk of diarrhea was higher among the households without latrine 6.242 ($p=0.044$). The presence of sanitation of drinking water storage areas was significantly associated with the presence of diarrhea in the last two weeks 6.115 ($p=0.047$) (Table 15).

From the total respondents, 113(28.2%) were those households who had latrine and who encountered diarrhea in the last two weeks of the survey. To the contrary, 41(10.2 %) of the respondents had neither latrine nor diarrhea in the last two weeks before the study.

From 270 households who had a latrine, diarrhea occurred in 46(16.9%) and 67(24.6%) of the household with latrine were good and poor in their sanitation respectively.

Table 15: Distribution of Factors associated with Under Five diarrhea at Robe and Ginnir towns of Bale Zone, South East Ethiopia, 2012

Characteristics	Is there diarrhea in the last two weeks			X ² (p-value)	
	Yes (%)	No, (%)	Total. (%)		
Latrine availability					
Yes	113 (28.2%)	157 (39.2%)	270 (67.3%)	25.440 (p=0.000)	
No	90 (22.4%)	41 (10.2%)	131(32.7%)		
Family size					
1-3	38 (9.5%)	90 (22.4%)	128(31.9%)	34.764 (p=0.000)	
4-6	121 (30.2%)	87 (21.7%)	208(51.9%)		
>=7	44 (11%)	21 (5.2%)	65 (16.2%)		
Sanitation of the latrine					
Good	46 (16.9%)	91 (33.5%)	137(50.4%)	7.215 (p=0.007)	
Poor	67 (24.6%)	68 (25.0%)	135(49.6%)		
Sanitation of drinking water storage areas					
Yes	143 (36.1%)	117(29.5%)	260(65.6%)	6.115 (p=0.047)	
No	58 (14.6%)	77 (19.4%)	135 (34.4%)		
Occupational status					
Governmental employee	40 (10.0%)	31 (7.7%)	71 (17.7%)	12.785 (p=0.005)	
Farmer	42 (10.5%)	30 (7.5%)	72 (18.0%)		
Merchant	50 (12.5%)	33 (8.2%)	83 (20.7%)		
Housewife	71 (17.7%)	104(25.9%)	175(43.6%)		
Households without latrine					
Open field defecation	76 (57.6%)	36 (27.3%)	112(84.8.0%	6.242 (p=0.044)	
Farm land defecation	15 (11.4%)	3 (2.3%)	18 (13.6%)		
Others	0 (.0%)	2 (1.5%)	2 (1.5%)		

4.1.8. Logistic Regression Result

In the final full model, the independent variables which had the p-value of less than 0.05 were significantly affecting the under-five diarrhea

The final Logistic regression model

Logistic regression Number of obs = 372
 LR chi2(3) = 26.83
 Prob > chi2 = 0.0000
Log likelihood = -244.30129 Pseudo R2 = 0.0521

Diarrheal last two weeks	Odds Ratio	Std. Err.	z	P> z	[95% Conf. Interval]	
Location Source	.3184979	.0853541	-4.27	0.000	.1883621	.5385421
Area sanitary	.5542563	.1357829	-2.41	0.016	.342911	.8958594
Sanitation of latrine	1.681411	.3847925	2.27	0.023	1.073682	2.633129
constant	4.264814	2.205714	2.80	0.005	1.547634	11.75255

From the final full model; Location of the water source, sanitation of storage area and sanitation of latrine were significant factors for under-five diarrhea having a significant level (P-value of less than $\alpha=0.05$).

As a conclusion, those households having convenience location of water source were 68% less likely to have under-five diarrhea, the households having sanitation for their storage drinking water are 45% less likely to have under-five diarrhea in their home, and those households having poor latrine sanitation are 68% more likely to have under-five diarrhea in their home.

4.2. Physico-chemical and Bacteriological Water Analysis of water samples from Ginnir and Robe towns

A total of 11 samples of water were taken for physicochemical analysis. Five water samples were from spring sources, three samples from boreholes and three samples

from main reservoirs in the study area. Sixty samples were taken at household level from respective towns for bacteriological analysis (Table 16)

Table 16: Characteristics of water sources taken for physicochemical analysis from Robe and Ginnir towns of Bale Zone south East Ethiopia

Characteristics	Number	Percentage
Sites of water sources		
Robe	9	70
Ginnir	2	30
Total	11	100
Types of water sources		
Spring	5	45.4
Borehole	3	27.3
Main reservoirs	3	27.3
Total	11	100
Water sample at household level		
Robe	30	50
Ginnir	30	50
	60	100

4.2.1. Physical Quality Parameter of Drinking Water in Robe and Ginnir Towns

Hydrogen Concentration: The highest mean pH of water sample was recorded from borehole three of Robe town which was 8.05 and the minimum mean pH of water sample was recorded from Tsebele I (spring) of Ginnir town which was 7.37.

Temperature: The highest mean temperature was recorded from Tsebele II (spring) of a water sample from Ginnir which was about 27.9°C and the lowest mean Temperature was recorded from a water sample of Oda spring in Robe town which was madda, spring 16 °C All water sample has had a temperature of above 15°C. The detail of the physical quality of sample water is depicted in Table 17.

Table 17: Mean Distribution of physical Quality parameter of drinking water in Robe and Ginnir towns of Bale Zone South East Ethiopia

Source waters	Physical parameters: Mean, SD		
	T(°C)	pH	Turbidity(NTU)
Oda spring	17[±2.00]	7.42[±0.05]	3.23[±1.30]
Madda spring	16[±2.50]	7.89[±0.06]	3.48[±1.10]
Robe Kesimira	19[±1.50]	7.89[±0.02]	3.82[±1.20]
Ginnir Tsebele I	21[±0.3]	7.05[±0.31]	5.55[±1.30]
Ginnir Tsebele II	27.9[±0.6]	6.95[±0.22]	3.62[±1.80]
Robe Borehole III	19.5[±1.5]	8.05[±0.05]	4.71[±1.10]
Robe Borehole III	19.5[±0.20]	7.88[±0.04]	4.55[±1.60]
Robe Borehole I	19.8[±0.30]	7.97[±0.03]	5.42[±1.40]
Robe reservoir	22.2[±0.40]	7.54[±0.30]	2.36[±1.45]

Turbidity:-The highest and lowest turbidity measurements were recorded from water source samples of Ginnir Tsebele I and Robe Borehole 5.55±1.45 NTU 5.42±1.3NTU respectively. The lowest turbidity level was found in Robe main reservoir which was about 2.36NTU.

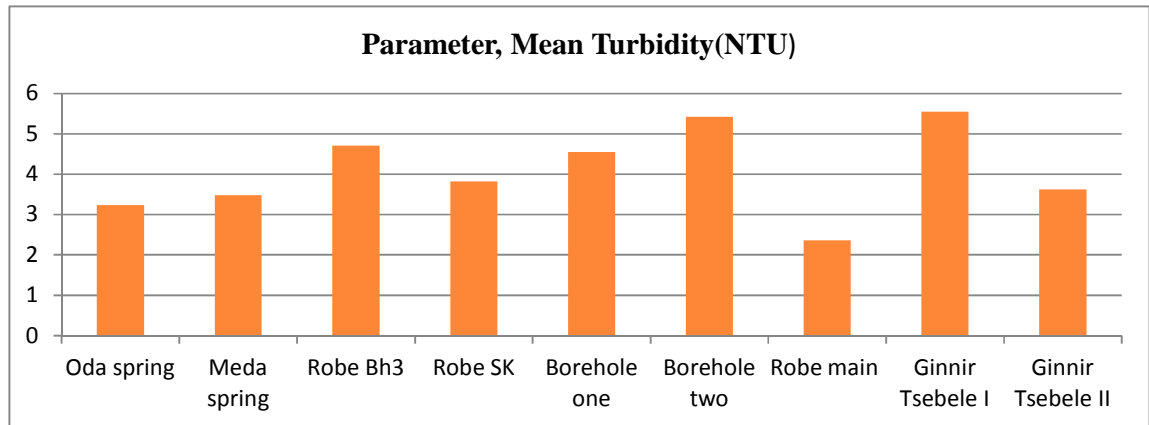


Figure 28: Turbidity values of water samples selected from Ginnir and Robe Town, 2012

4.2.2. Chemical Parameters of Sample Water from spring water Sources

The result from the below table showed that,

Fluoride (F⁻):-This study revealed that the fluoride content of Robe Oda spring was zero while that of Ginnir Tsebele two of Ginnir town had fluoride content of 0.84mg/l.

Nitrate (NO₃⁻): - The maximum nitrate value was determined in Ginnir Tsebele one of Ginnir town (36.96mg/l) while the minimum was in the main reservoir of Robe town (0.26mg/l).

Fe²⁺:- Maximum mean value of iron was found in Borehole one of Robe water sources while the minimum was found in Ginnir Tsebele one of the water sources.

Table 18: Mean Distribution of Chemical Quality parameter of drinking sample water from spring in Robe and Ginnir towns of Bale Zone South East Ethiopia, 2012

Source waters	Chemical parameters: Mean Values(mg/l), sd						
	TDS	CU ²⁺	Fe ²⁺	Mn ²⁺	SO ₄ ²⁻	NO ₃ ⁻	F ⁻
Oda spring	54	0.06	0.07	0.2	2	15.32	0.00
	±3.5	±0.01	±0.01	±0.00	±0.00	±1.5	
Madda spring	56	0.04	0.02	0.00	2	10.34	0.24
	±2.2	±0.00	±0.01		±0.03	±1.25	±0.01
Robe KS spring	220	0.04	0.09	0.06	12	20.68	0.39
	±4.5	±0.00	±0.01	±0.01	±0.8	±1.2	±0.02
Ginnir Tsebele I	208	0.13	0.05	0.01	34	36.96	0.72
	±6.8	±0.00	±0.00	0.00	±3.5	±2.25	±0.04
Ginnir Tsebele II	265	0.46	0.03	0.00	11	26.4	0.84
	±5.6	±0.00	±0.00	±0.00	±1.2	±0.00	±0.04

Comparing to WHO standard, the iron concentration in the borehole of Robe town was higher than the recommended values which are 0.3mg/l.

Sulfate (SO₄²⁻) Maximum sulfate was observed in Ginnir Tsebele one and the lowest were observed in Robe Oda spring.

4.2.3. Chemical Parameters Sample Water from Boreholes

Fe^{2+} :- Maximum mean value of iron was found in borehole one of Robe water sources. Comparing to WHO standard, the iron concentration in the borehole of Robe town was higher than the recommended values which are 0.3mg/l. Higher TDS was found In borehole water samples and Ginnir springs (Tsebele) one and two (Table 19)

Table 19. Mean Distribution of Chemical Quality parameter of drinking sample water from selected boreholes in Robe town of Bale Zone South East Ethiopia.2012.

Source waters	Chemical parameters: Mean Values(mg/l), SD						
	TDS	Cu^{2+}	Fe^{2+}	Mn^{2+}	SO_4^{2-}	NO_3^-	F^-
Robe BH3	274	0.15	0.70	0.08	24	20.68	0.26
	±6.5	±0.00	±0.01	±0.01	±1.5	±15	±0.02
Robe BH 1	230	0.02	1.1	0.00	27	25.96	0.2
	±7	±0.00	±0.00		±2.5	±2.25	±0.01
Robe BH 2	302	0.04	0.8	0.00	27	34.2	0.32
	±8.5	±0.00	±0.00		±3	±2.22	±0.02

SD indicates Standard deviation.

Higher Iron concentration above 1mg/l was recorded from Robe borehole I, about 27mg/l sulfate from Robe borehole I and 25.96mg/l nitrate was recorded from Robe borehole 2(Fig 25).

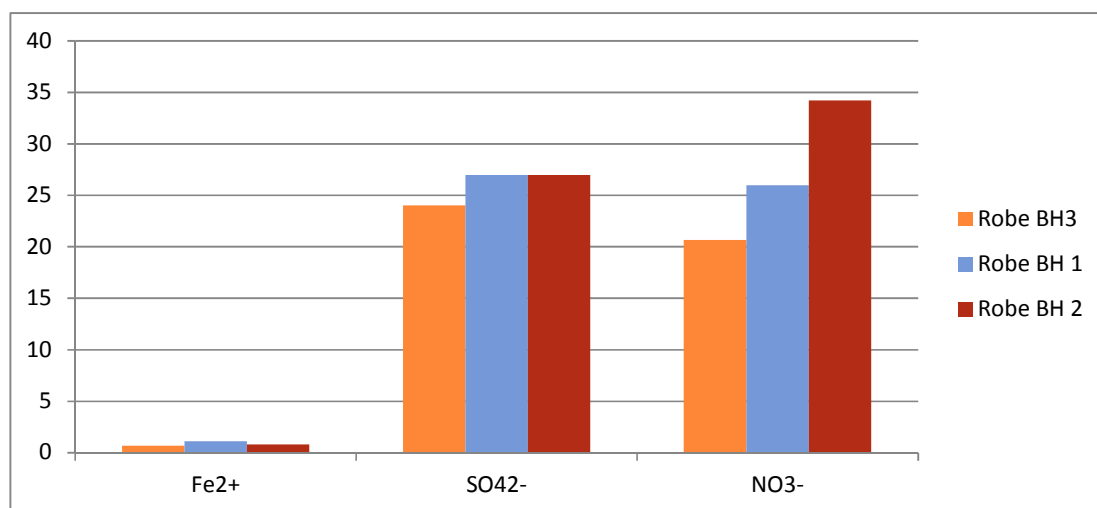


Figure 29: Concentration of iron, sulfate, and Nitrate in Robe Borehole sample waters

4.2.4. Chemical Parameters of Sample Water from Reservoirs

A water sample from Robe R1 has A mean of TDS of 274mg/l, Robe R2 55.9mg/l and Robe R3 53.9 mg/l. a water sample from Robe R1 has higher sulfate and nitrate compared to the Water sample from Robe R1 and R2. However, all recorded values were within range of WHO recommendation (Table 20).

Table 20 Mean Distribution of Chemical Quality parameter of drinking sample water from reservoir in Robe town of Bale Zone South East Ethiopia

Source waters	Chemical parameters: Mean Values(mg/l), sd						
	TDS	Cu ²⁺	Fe ²⁺	Mn ²⁺	SO ₄ ²⁻	NO ₃ ⁻	F ⁻
Robe R1	274	0.15	0.70	0.08	24	26.0	0.28
	±6.5	±0.00	±0.01	±0.01	±1.5	±0.00	±0.02
Robe R2	55.9	0.05	0.11	0.2	2.2	11.5	0.06
Robe R3	53.9	0.03	0.02	0.01	3	10.3	0.33

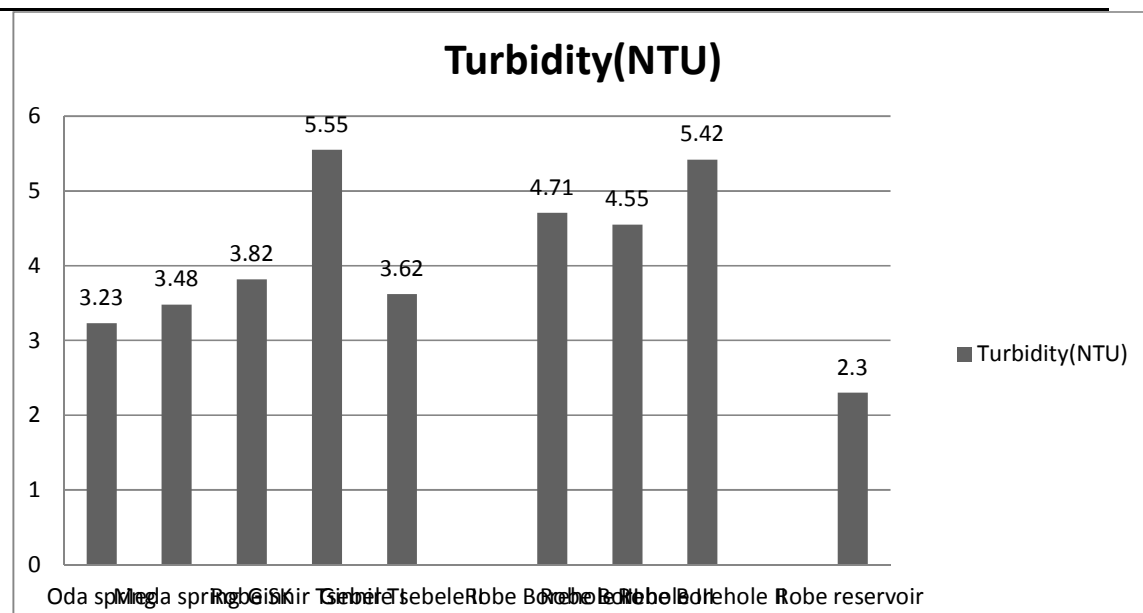


Figure 30: Turbidity measurements in springs, borehole and reservoirs at Robe and Ginnir towns of Bale Zone, Southeast Ethiopia, 2012.

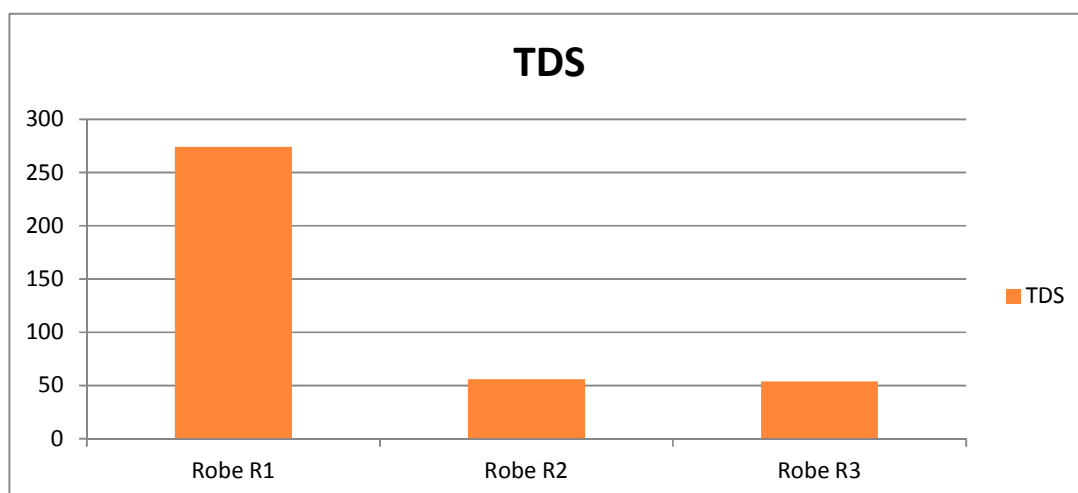


Figure 31: TDS at three Robe reservoirs, 2012

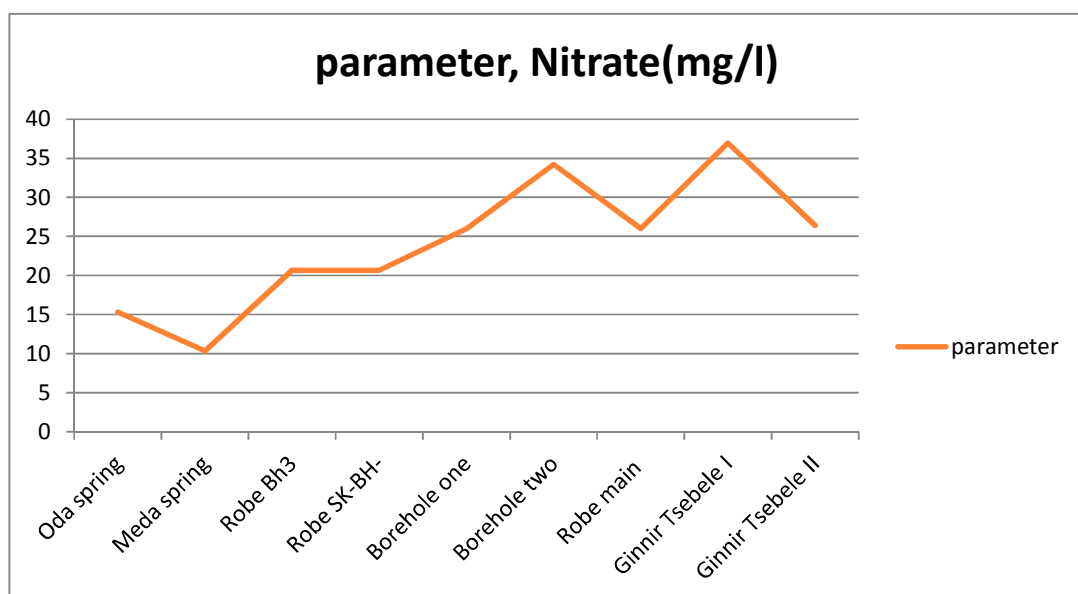


Figure 32: Nitrate concentration in selected water samples of Robe and Ginnir towns, 2012.

Total dissolved solids (TDS):- In this study high TDS was found in Borehole water sources of Robe town and the spring water sources of Ginnir town. The lowest TDS was observed in Oda spring of Robe town (Fig 29).

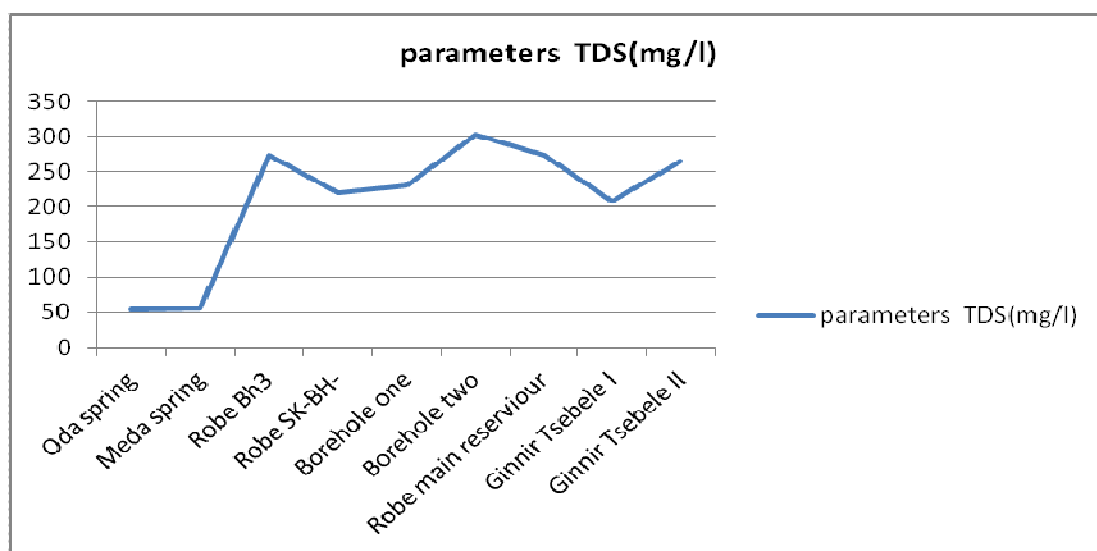


Figure 33: Total dissolved solids in selected water sources in Robe and Ginnir town, 2012.

Table 21: Mean Values of Physicochemical parameters by types of water sources in Robe and Ginnir Towns, 2012

	TDS	Cu^{2+}	Fe^{2+}	Mn^{2+}	SO_4^{2-}	NO_3^-	F^-
Robe Spring	110	0.046	0.06	0.087	5.33	15.45	0.21
Robe Borehole	268.7	0.07	0.87	0.027	26	26.94	0.26
Ginnir Spring	236.5	0.295	0.04	0.005	22.5	31.68	0.78
Robe Reservoir	127.9	0.077	0.28	0.097	9.73	15.93	0.37

Regarding Iron concentration in selected water sources in Ginnir and Robe towns, a higher concentration was found in Borehole of Robe town (Table 21).

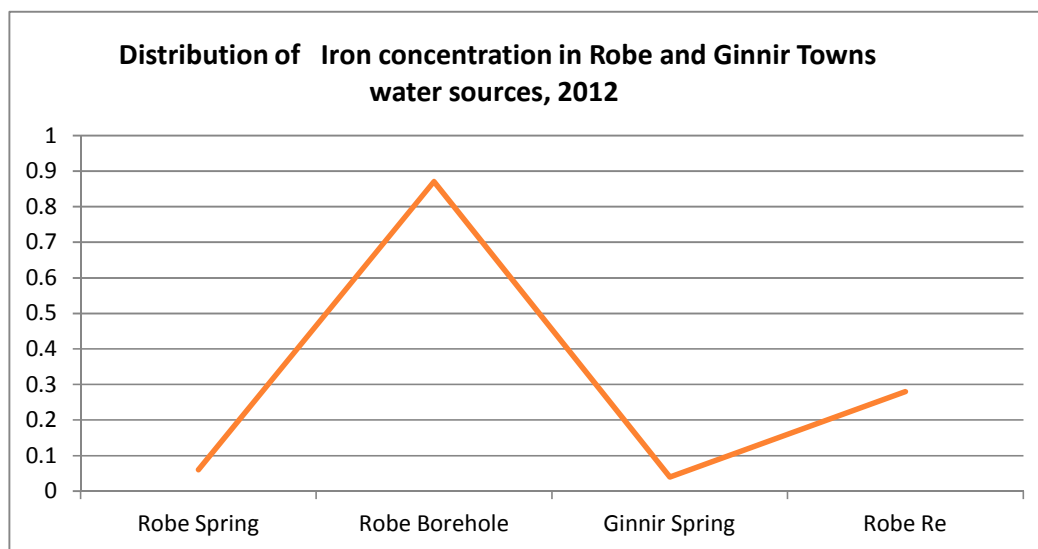


Figure 34 Distribution of Iron Concentration in Robe and Ginnir Towns Water Sources, 2012

Higher sulfate concentration was found in water sources of Ginnir town and Robe Boreholes, However, the lowest in Spring of Robe Town (fig. 31).

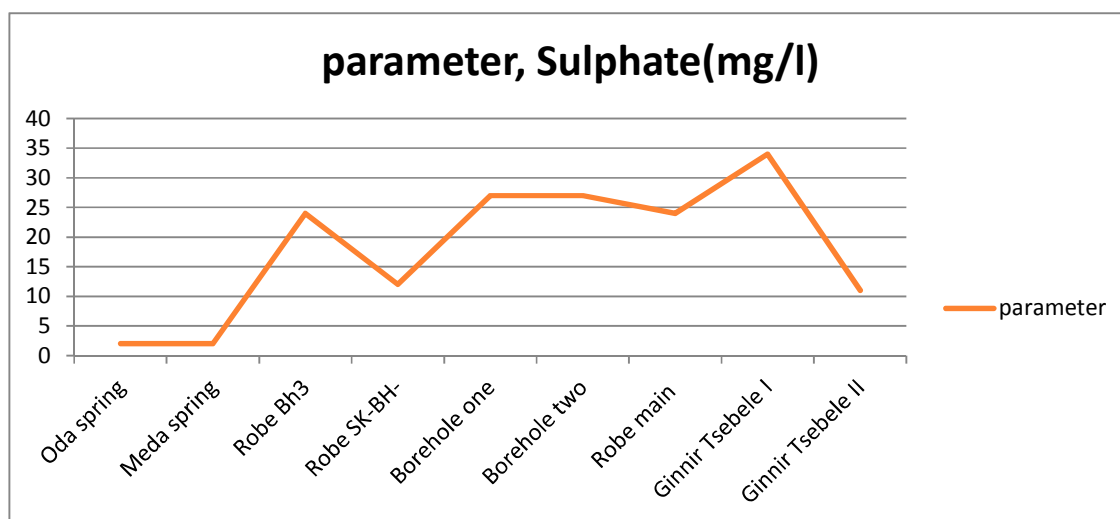


Figure 35: Sulfate concentration in selected water sources in Robe and Ginnir town, 2012

Table 22: The average values of Physicochemical parameters of selected water samples by World Health Organization standard

Parameters	Oda spring	Meda spring	Kesimira spring	Borehole I	Borehole III	Borehole II	Robe Reservoir	GinnirTsebel e I	GinnirTsebel e II	WHO Standard
T(°C)	17	16	19	19.5	19.5	19.8	22.2	21	27.9	<15(0°)
pH	7.42	7.89	7.89	7.88	8.05	7.97	7.54	7.05	6.95	6.5-8.5
Turbidity(NTU)	3.23	3.48	3.82	4.55	4.71	5.42	2.36	5.55	3.62	5NTU
TDS(mg/l)	54	56	220	230	274	302	274	208	265	500mg/l
Fe ²⁺ (mg/l)	0.07	0.02	0.09	1.1	0.7	0.8	0.7	0.05	0.03	0.3mg/l
SO ₄ ²⁻ (mg/l)	2	2	24	27	24	27	24	34	11	500mg/l
NO ₃ ⁻ (mg/l)	15.32	10.34	20.68	25.69	20.68	34.2	26	36.96	26.4	50mg/l
F ⁻ (mg/l)	0	0.24	0.39	0.2	0.26	0.32	0.28	0.72	0.84	1mg/l
Cu ²⁺ (mg/l)	0.06	0.04	0.04	0.02	0.15	0.04	0.15	0.13	0.46	

Turbidity, Iron Concentration was found above the WHO recommended value in the study area and all other parameters observed in water sample were under the recommended value in drinking water.

4.2.5. Physico Chemical Quality Parameters Correlations

In this study, Cu²⁺ shows significant positive correlation with TDS ($r = 0.705$, $P = 0.023$), Temperature ($r = 0.862$, $P = 0.001$) and Mn²⁺ ($r = 0.765$, $P = 0.010$). A significant positive correlation was also found between SO₄²⁻ & NO₃⁻ ($r = 0.638$, $p = 0.047$), SO₄²⁻ & Temperature ($r = 0.635$, $p = 0.048$) and SO₄²⁻ & TDS ($r = 0.728$, $p = 0.017$). Turbidity has also positive correlation with NO₃⁻ ($r = 0.821$, $p = 0.004$) and negative significant correlation with Mn²⁺ ($r = -0.677$, $p = 0.031$). This shows that with increase or decrease in the values of either of correlated quality parameters also reveal decrease or increase in their values (Table 23).

Table 23: Correlation coefficient between Physicochemical quality parameters of drinking water at Robe and Ginnir Towns of Bale Zone, Southeast Ethiopia, 2012

Paired parameters		Pearson correlation	Sig.(2-tailed)
Pair 1	Cu^{2+} & TDS	0.705	0.023*
Pair 2	SO_4^{2-} & TDS	0.728	0.017*
Pair 3	F^- & TDS	0.799	0.006**
Pair 4	Temp. & TDS	0.862	0.001**
Pair 5	NO_3^- & Turbidity	0.821	0.004**
Pair 6	Mn^{2+} & Turbidity	0.677	0.031*
Pair 7	Mn^{2+} & Cu^{2+}	0.765	0.010**
Pair 8	SO_4^{2-} & NO_3^-	0.638	0.047*
Pair 9	SO_4^{2-} & Temp.	0.635	0.048*

**, Correlation is significant at the 0.01 level; *, Correlation is significant at the 0.05 level.

Electrical Conductivity (EC): EC measurement is an excellent indicator of TDS, which is a measure of salinity that affects the taste of potable water. The conductivity of water is a measure of the capacity of a solution to conduct electrical current through it and depends on the concentration of ions and load of nutrients. Electrical conductivity is used to indicate the total ionized constituent of water.

Total Hardness: Hardness is a very important parameter in decreasing the toxic effect of the poisonous element. In this study the total hardness in water sample Robe 2 was 38 mg/l in CaCO_3 , Robe 3 was 45 mg/l in CaCO_3 , GI 198 mg/l in CaCO_3 and 220 mg/l in CaCO_3 in GII.

Table 24: Hardness concentration, TDS and EC of selected water samples from springs and reservoirs at Ginnir and Robe Towns, 2012.

<i>Parameters</i>	<i>Values obtained</i>			
	Robe R2	Robe R3	GT1	GT2
TDS mg/l	55.9	53.9	208	265
EC $\mu\text{s}/\text{cm}$	111.5	108.1	416	529
T. Hard. as CaCO_3 mg/l	38	45	198	220
Ca hard as CaCO_3 mg/l	24	25	120	141

Mg hard as CaCO ₃ mg/l	14	20	78	79
T. Alk CaCO ₃ mg/l	48	51	206	246
HCO ₃ ⁻	58.56	62.22	251.3	300.1

GT1=GinnirTesbele I, GT2= GinnirTsebele 2, R= Reservoir

As shown in above table, the mean electrical conductivity (EC) of the water samples from Robe 2 was 108.1 µs/cm, Robe 3 was 11.5 µs/cm, GI was 416 µs/cm and GII was 529 µs/cm.

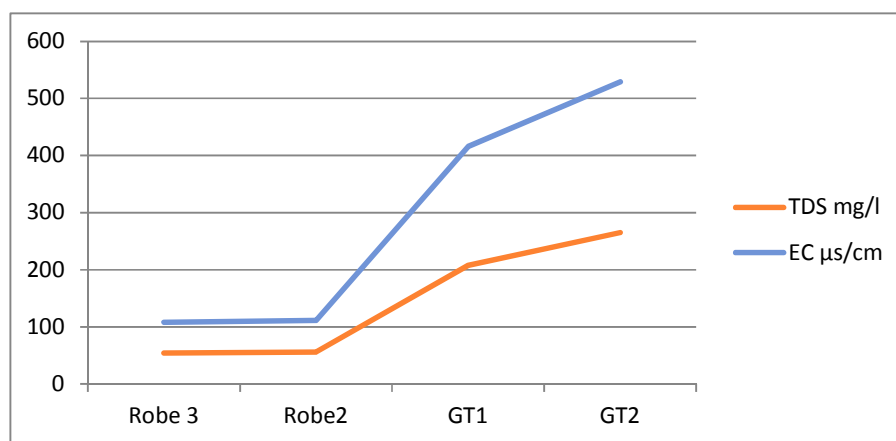


Figure 36: TDS versus EC of selected water samples, 2012

Table 25: Bacteriological water quality analysis Public Fountains in Robe town result

s/n	Total coliforms (CFU/100ml)	frequency		Fecal coliforms (CFU/100ml)	
		N	%	N	%
1	10-100	2	6.67	6	20
2	1.01-9.99	11	36.67	18	60
3	0.01-1.0	8	26.67	0	0
4	0	9	30	6	20
Total		30	100	30	100

Table 26: Bacteriological water quality analysis Public Fountains in Ginnir town result

s/n	<i>Total coliforms</i> (CFU/100ml)	<i>frequency</i>		<i>Fecal coliforms</i> (CFU/100ml)	
		<i>N</i>	<i>%</i>	<i>N</i>	<i>%</i>
1	10-100	28	93.3	11	36.7
2	1.01-9.99	2	0.7	14	46.6
3	0.01-1.0	0	0	0	0
4	0	0	0	5	16.6
Total		30	100	30	100

4.2.6. Evaluation of the treatment efficiency of *Moringa stenopetala* seed for selected parameters

4.2.6.1. Turbidity Removal efficiency of the *Moringa stenopetala* seed powder

The treatment efficiency of the *Moringa stenopetala* seed for turbidity, hardness, and nitrate concentration was evaluated by applying different coagulant doses.

Ten water samples were taken at the household level to evaluate turbidity removal efficiency of *Moringa stenopetala* seed powder. The mean initial turbidities of sample water taken at household level were about 6.83NTU. Different doses of seed powder were added to samples of waters. A 25mg/l of *Moringa* powder was added to this sample water and its initial turbidity level was reduced by 70.46% (from 6.23 NTU to 1.84NTU), 50mg/l reduced the turbidity from 4.3 NTU to 1.06 NTU (by 75.34%), a 75mg/l was reduced the turbidity from 4.49NTU to 1.07 NTU (by 76.6%) (Fig. 35).

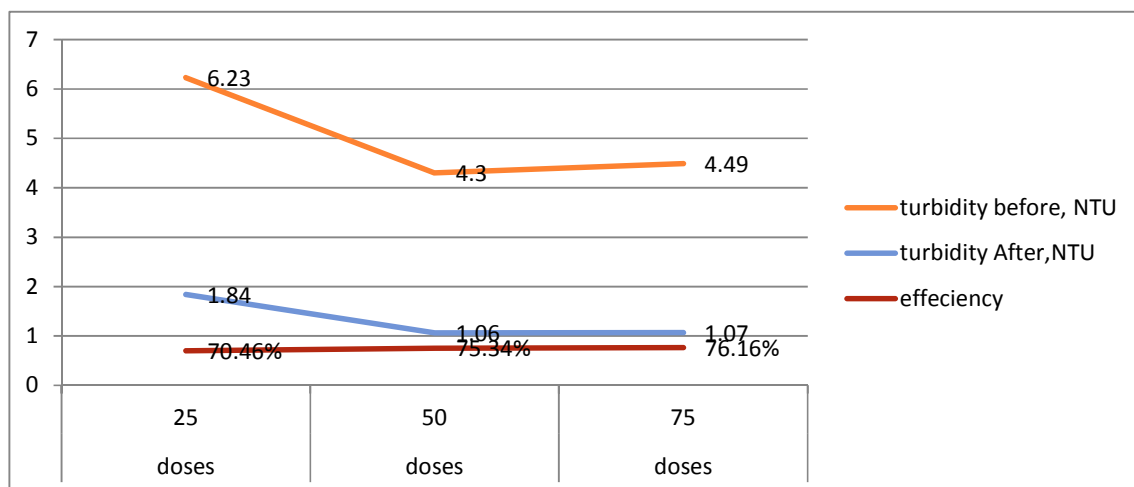


Figure 37: Turbidity Removal efficiency of *Moringa stenopetala* seed in selected water samples in the study area, 2012

4.2.6.2. Nitrate Removal Efficiency of the *Moringa stenopetala* Seed Powder

To evaluate nitrate removal efficiency *Moringa stenopetala* seed powder, five water samples were taken from sources in the study area. Then the nitrate concentration of each water sample was analyzed and recorded. Different doses of *Moringa stenopetala* seed powder were then added to these water samples with a determined level of nitrate concentration. The result indicated that *Moringa stenopetala* seed powder has the ability to remove the nitrate concentration in water. A 100mg/l dose of the seed powder reduced the nitrate concentration form 21.3mg/l to 3.1mg/l and 200mg/l doses from 5.49mg/l to 8.18mg/l. This indicated that as Dose of *Moringa stenopetala* seed increases, the removal efficiency of nitrate increases per the nitrate level of each water samples (Fig.34).

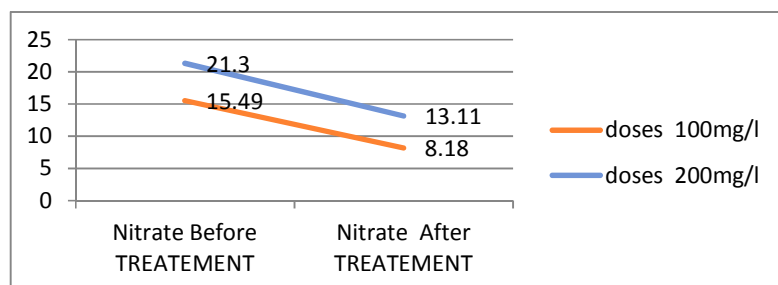


Figure 38: Nitrate removal efficiency of *Moringa stenopetala* seed in selected water samples in the study area, 2012

4.2.6.3. Total Hardness Removal Efficiency *Moringa stenopetala* Seed Powder

To determine the hardness removal efficiency of *Moringa stenopetala* seed, initial and final total hardness of sample water was evaluated.

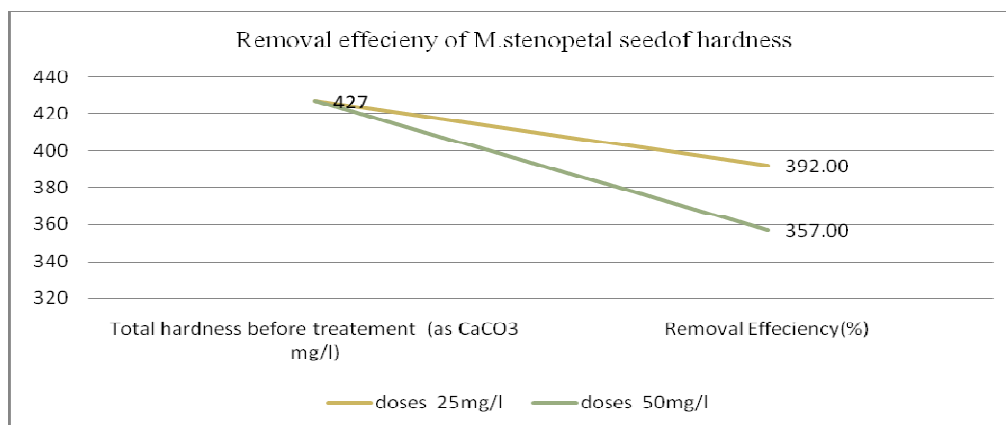


Figure 39: Total Hardness Removal efficiency of *Moringa stenopetala* seed powder in selected water samples in the study area, 2012.

The *Moringa* seed powder dose used in the treatment ranges from 25mg/l to 225 mg/l. The mean initial value of the total hardness, 427 was recorded the sample water. After 12hr treatment, the total hardness was reduced by 7.8%. Different doses of *Moringa stenopetala* seed were then added to this water sample with a determined level of total hardness. The result indicated that *Moringa stenopetala* seed powder has the ability to remove the total hardness of water. As the Dose of *Moringa stenopetala* seed increases, the removal efficiency of hardness increases.

Chapter 5: Discussion

5.1. Sanitation-Hygiene Practices and childhood diarrhea among households in Robe and Ginnir town of Bale Zone Oromia Regional state South East Ethiopia

As reported by Teferi (2007), protection of water supply from contamination is the first line of protection against disease. Though, failure to provide adequate protection, poor site selection, and un-hygienic practices of the consumers regarding water collection, transportation, storage & deterioration of construction materials may contribute the contamination of water sources and result in water-borne diseases. Community un-hygienic practices increase the sanitary risk of the water sources, water sources with a high sanitary risk score had unacceptable water quality. This study assessed the sanitary condition of six protected springs found in Robe and Ginnir Towns of Bale Zone. This study found that Tseble I and II of Ginnir Spring, Madda Spring and Kaso Shekmera Spring of the Robe town were found at high risk of sanitary practices, while Oda and Werabo Spring of Robe town were at intermediate risk of sanitary practices. The reason behind the variability of sanitary risk scores between water sources may be due to different factors like un-hygienic practices near the water source, lack of protection/fences, lack of surface water diversion ditch and others.

In this study, the majority of the respondents were found to collect 37.9%, from tap water, and 30.4% from protected spring. This is supported by a study from Dukem that showed the majority of households had obtained drinking water from private piped water inside the compound followed by households that brought water from neighborhoods private piped tap and only 0.5% obtains drinking water from protected spring (Mohammed, 2011).

This difference might be due to the high coverage of drinking water in former town, socioeconomic differences of the population, availability, and access to improved municipal piped water and differences development status of the towns. In many developing communities, household water is managed exclusively by women.

Women and girls are generally the ones who obtain water for the home, transport it, store it and then use it for various household purposes (UNICEF, 2008). This study also found that housewife were highly responsive to collect water, followed by children's and housemaids to fetch water from a source.

According to UNICEF, (2008), numerous types of vessels are used to store and transport water in developing countries this study found that a majority of the respondents use jerrican both for the collection and storage of the water. This current result was in harmony with the finding in Dire Dawa Administrative Council; Ethiopia that revealed that jerrican was mostly used for water collection and storage (Desalegn et al. 2013).

All water containers should be clean and the top of the water container should be covered to stop dust and other contaminants falling into the drinking water. It is best for water to be poured from the container to prevent contact with dirty fingers and hands. When scooping is used to take water out of the storage container they should keep inside the water storage jar and never be placed on the floor (Howard, 2002).

In this study, (69.8%) of the respondents cleaned their container before refilling storage containers which was much higher than a study done in Dire Dawa town 55.5% (Desalegn et al. 2013). Similarly, (81%) of the respondents covered their water storage container, which was higher than the result from Dire Dawa town (52%) (Desalegn et al. 2013), Garmuleta district (60%), and Kidame Gebeya (58%), but almost comparable with finding from a study done in South Wollo, 92.7% (Seid, Legesse and Kebede, 2003). This indicated that the people in the current study area had better water handling practice than the other areas stated.

Unrestricted and un-hygienic water collection and storage activities were the main contributors for household water contaminations (Thomas, C, Cairn cross, and S. 2004)). in this study, about 34.9% of the respondents dipped out water to collect from the storage container. This practice was lower than the finding from Zambia with 80 % (Sutton and Dominic, 1989) South Wollo with 72 % (Seid T et al. 2003),

Dire Dawa administrative city with 85.41% (Desalegn et al. 2013) of the households was dipped out from the container. The reason for these differences might be due to that the households in the current study used jerrican for water collection and storage at home which is inconvenient for dipping in the study.

Improved sanitation also brings advantages for public health, livelihoods and dignity advantages that extend beyond households to entire communities. There is no doubt that the combination of safe drinking water and hygienic sanitation facilities is a precondition for health and success in the fights against poverty, hunger, child mortality, and gender inequality (UNICEF/WHO 2013 and UNDP, 2006.).

It is reported that the overwhelming communicable disease burden in Ethiopia is attributable to poor sanitation and hygiene. The environment is deteriorating from time to time as the solid waste is not properly collected and treated (FDRE/MOH 2005). In this study, solid waste management practices of the respondents' were 48.1% disposed their solid wastes (mostly garbage) in their pit and followed by 29.2% who were burning it as a solid waste management practices.

A study from Dukem town of Ethiopia revealed that about two-thirds (153, 67.7%) of the total sampled households had a temporary storage container in their compound. However, about 40.9% of the households did not cover their solid waste container and left unprotected which might expose household members to the risk of waste contamination (Mohammed, 2011). In the present study, about 46.6% of households were storing the refuse undercover materials in order to prevent the risks of diseases secondary to these wastes.

Domestic waste, when sorted, recycled well or composted, can be turned into a resource, but it was found that the greater part of waste generated generally did not undergo such process before the final disposal. The study result indicated that only 2.2 % of the sampled households had used waste as manure (compost) for home gardening. This finding is consistent with finding in another town of Ethiopia, which

revealed that about 4.9% of the sampled households had used waste as manure (composts) for home gardening (Mohammed, 2011).

According to WHO (2009), the majority of households were using unsafe solid waste disposal methods open field disposal, burning of waste within the premises disposal outside premises anywhere and within premises anywhere. This practice of open dumping, particularly around households represents a major health risk to residents. Poorly managed waste presents a health risk to communities. This is primarily because improperly disposed waste can be a source of contaminants and breeding sites. For the hygiene situation of households to improve, it must have easy access to working and hygienic toilet facilities (EHP, 2004).

Report from FMOH, (2009), revealed that the National Hygiene and Sanitation Strategy of Ethiopia call for all households have access to, and use a sanitary latrine. Accordingly, during the household survey, information was elicited about the availability of toilets in the households. However, in the present study, about 32.7% of households did not have any types of a latrine at their home. The main reasons for not having a latrine were high cost/lack of money and lack enough space.

Almost all the types of the latrine used in the study area were a pit latrine. This is consistent with figures reported by AMCOW; Majority of latrine used at household level was a traditional latrine (AMCOW, 2010). It is also in line with from Dukem Town of Ethiopia, which revealed that about 55% of the latrine was a traditional pit latrine. However, still, practices of open field defecation are high in the study area in which about 84.8% reported for open field defecation. The results from observation also confirm that presence of latrine in households didn't indicate its proper utilization since feces were commonly observed on the premises of households in the study area. This finding is completely in contrary with results from Burundi, which revealed that none of the study subjects used the open field for defecation and about 93% were used pit latrine without slab for defecation (Katharina, 2014).

The result of latrine utilization showed less number of households uses their latrine frequently. This finding was similar to a study conducted in Malaysia; among the study subjects which had a latrine, 88.5% used the latrine frequently, 11.1% were

sometimes and 0.4% never used at all. Concerning the sanitation of the latrine, only 50.4% were found in a good condition. The study communities had sufficient awareness of sanitation and household water management, but still, their practice in using the facility was poor and health impact reduction still marginal.

This study found high magnitudes of under five diarrhea cases in the study area. This is due to practices of open field defecation in the study area. This is supported by a study by Emerson and Luby which demonstrated that the importance of toilet construction and hygiene promotion in controlling fly breeding, reducing diarrhea by 23 percent (Emerson 2000 and Luby, 2005).

5.2. Physicochemical quality of drinking water

Temperature is one of the Physico-chemical parameters used to evaluate water quality of potable water. The data showed that the highest temperature of 27.9°C from source water of Ginnir Spring, whereas the lowest mean record of 16°C was measured from the Mada spring of Robe town.

A similar study conducted in Ziway, a town located near the study area, showed a mean temperature of 23.2°C from different water source samples (Kassahun, 2008), whereas a mean temperature record of 23.8°C was measured from the drinking water source supply of Bahir Dar town (Getnet, 2008). A slightly higher temperature of 25.5°C was reported from water source samples from Nigeria (Agbogu et al, 2006). The temperature records of all water samples in the stated area did not meet the WHO standard of <15°C (WHO, 1997) which is in line with the finding from the current study area.

The turbidity of the water is one of the important physical parameters that affect not only the quality of water but also other chemical and bacteriological parameters and efficiency of the treatment of water (WHO, 2006). The consumption of highly turbid water may constitute a health risk as excessive turbidity can protect disinfection of pathogenic organisms. The highest and lowest turbidity measurements were recorded from water source samples of Ginnir Spring (Tsebele II) and Oda Robe spring of Robe with 5.55NTU and 3.23NTU, respectively. This turbidity often occurs following

rainy months when rapidly flowing surface runoff carries sediments into the river and a lot of wastes are added to local water sources. Consumption of water from the spring without further treatment for turbidity may constitute a health risk as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants, and also stimulate the growth of bacteria during storage (Chan et al., 2007).

The TDS values of the different water sources of the study area (54mg/l-274mg/l) were found to be less than the 475.3mg/l records from hand-dug wells from Benishangul Gumuz (Mebratu, 2007). Similarly, the EC records of the same water source of Ginnir town spring was found to be 5290 μ S/cm which was lower than that of a water sample from Debrezeit, which was about 559.0 μ S/cm and the water sources from Nigeria which was about 277.95 μ S/cm (Agbogu et al., 2006).

The range of p^H for spring was 6.95-7.89, for Borehole 7.88-8.05. The maximum p^H was recorded from Robe Borehole and the minimum P^H was recorded from Ginnir Spring. Different studies conducted in the country revealed different P^H values of different water sources. A study from water sources at Akaki Kaliti sub-city of Addis Ababa reported P^H of 7.6 (Mengstayehu, 2007), a record of pH 8.3 from water sources in Ziway town (Kassahun, 2008), and measurement of pH of 7.8 from Adama (Nazareth) town (Temesgen, 2009). Another study from Debrezeit also reported a P^H of 7.2 from water sample selected from the well. Even though a slight difference in P^H values of water sources, P^H values of all selected water samples from water sources were within the recommended standard limits of 6.5-8.5 (WHO, 1997; NGL, 2002).

The pH should preferably be less than 8; however, lower-pH water is likely to be corrosive. A higher pH value requires longer contact time (CT) and high FCR for effective chlorine disinfection (ADWG, 1996). The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems (WHO, 2008). However, the source water in the study area poses no problem to be used as a drinking water source in terms of pH value parameters.

The detection of nitrate is an important water quality indicator that shows organic matter pollution due to microbial activity, or the downward -leaching and accumulation of nitrate from the surface (Karavolsos et al, 2008). In the present study, the concentration of nitrate in selected water sample was 36.96 mg/l in Ginnir spring (Tsebel I) and the minimum value was recorded from a water source in the reservoir of Robe town.

The study conducted at Debrezeit reported that the nitrate means the concentration of 12.3mg/l from water from wells, 10.8 mg/l from source water of Ziway (Kassahun, 2008), 12.9mg/l from sources of water of Bahir Dartown (Getnet, 2008).

The highest nitrate content of water source samples measured in this study is comparable to the maximum values of 10.8mg/l and 12.9mg/l from source waters of the Ziway town (Kassahun, 2008), and Bahr Dar town (Getnet, 2008) respectively.

This shows the nitrate contents of water source samples in Ginnir spring(Tsebel I) show organic matter pollution due to microbial activity and more often associated with contamination by excessive use of fertilizers (both inorganic and organic), in combination with inappropriate farming practices and/or sewage in the study area. It might be also due to plant residues, animal manures and human wastes decompose in the study area. Contamination of drinking water by nitrate is more commonly associated with some form of pollution resulting from human activities. Nitrates are very soluble in water and can move easily through soil. Over time nitrates can accumulate in groundwater that may then be used as a drinking water source (USEPA, 1999).

Electrical conductivity (EC) which is a measure of water's ability to conduct an electric current is related to the number of dissolved minerals in water, but it does not give an indication of which element is present, but higher value of EC is a good indicator of the presence of contaminants such as sodium, potassium, chloride or sulphate (Orebiyi et al., 2010).

Analysis of the results of four sample water from the study area shows that the maximum EC was found in the sample water form Ginnir spring (Tsebel II) 529

$\mu\text{S}/\text{cm}$ and $111.5 \mu\text{S}/\text{cm}$ from Robe Reservoir II. The EC values of all water samples were above the WHO standard limit $250 \mu\text{S}/\text{cm}$. A study conducted in the urban area of Tigray region revealed that the maximum of EC in drinking sample water was $2130 \mu\text{S}/\text{cm}$ and the minimum (44.1) from Abiyi-Addi water sample (Gebrekidan M, Samuel Z, 2011). This highest EC in sample waters may indicate the TDS concentration in drinking waters.

According to WHO, (2004), water quality concerns are frequently the most important part of measuring access to improved water sources. Acceptable quality shows the safety of drinking water in terms of its physical, chemical and bacteriological parameters.

5.3. MORINGA STENOPETALA SEED POWDER FOR WATER TREATMENT

To improve the quality of water, treatment plants use chemical coagulants in an effect to provide quality water. However, chemical coagulants found to have health and environmental problems and their required hard currency to import. Recently there has been increased interest in the subject of natural coagulants for treatment of water and wastewater in developing countries of major interest are the natural coagulants from tropical plants of the family of Moringaceae, which are *Moringa oleifera* and *Moringa stenopetala* were reported clarifying properties of turbid water (Jahn, 1981). This finding is in line with finding from Hawassa, in which admix of Moringa powder reduces the turbidity level of the sample water. The present finding is in line with the finding by Getachew, which stated that the medium fine particle of the seeds of *Moringa stenopetala* has shown an activity as a coagulant for the removal of water turbidity and $700 \text{ mg}/\text{L}$ of the dose removes about 94% of the water turbidity of the water sample taken from Awassa Lake and $600 \text{ mg}/\text{L}$ of the dose removes about 69% of water turbidity of the sample taken from Timbaho Monopol water source. Even though different water sample was used in later water source (Timbaho water source), the removal efficacy has increased as dose increased from $600\text{mg}/\text{l}$ to $700\text{mg}/\text{l}$ from 69% to 94%.

Chapter 6: Conclusion and Recommendations

Conclusion

Prevalence of childhood diarrhea was high and it is associated with lack of ease location of the water source, poor sanitation of drinking water storage and latrine. Prevalence of open field defecation was remarkably high. The iron content of drinking water was above the range of World Health Organization.

Water Handling Practices Related to Collection and Transportation

- The majority of the respondent were found using tap water for drinking and other purposes
- The majority of the households use jerrican for the collection and storage of the water
- More than two third of households cleaned their container before refilling storage containers
- The majority of households use pouring method to withdraw water from a storage container
- Types of storage container, location of water sources, and sanitation and area of water storage at household level were found associated with Under Five diarrhea cases prevalence at household level
- A large proportion of households had temporary solid waste storage container in their compounds; however, they do not practice covering of their solid waste container.
- Sanitary practices of selected water sources in the respective town were poor due to constructional defects, lack of follow up, bathing and laundry activities near the source.
- Most of the households did not use safe, solid waste disposal system.
- Almost all households use a pit latrine. However, open field defecation was still high in the study area.

Prevalence of childhood diarrhea

- The majority of households had soap in their households and had good personal hygiene practices during the study period.

- As a conclusion from the logistic regression model, those households having convenience location of water source are 68% less likely to have under-five diarrhea, the households having sanitation for their storage of drinking water are 45% less likely to have under-five diarrhea in their home, and those households having poor latrine sanitation are 68% more likely to have under-five diarrhea in their home.

Physicochemical parameter water in the study area

- p^H , Temperature, the turbidity of sample water from the spring was found within the permissible limit of WHO (2008) and ES (2001) ($< 15^{\circ}C$, 6.5 - 8 (6.5 - 8.5 for ES) and < 5 NTU) except the turbidity level of Ginnir spring which was about 5.55NTU.
- Temperature and turbidity of sample water from the three boreholes were found above WHO and ESG limit ($< 15^{\circ}C$, < 5 NTU).
- The turbidity of sample water from borehole was found within the permissible limit of WHO (2008) and ES (2001) ($< 15^{\circ}C$, 6.5 - 8 (6.5 - 8.5 for ES) and < 5 NTU), while the P^H of a water sample from borehole was found within WHO and ESG limit.
- Nitrate, TDS, sulfate, fluoride, and copper were found within the permissible limit of WHO (2008) and ES (2001).
- Iron was found higher than the WHO and ES guideline value of 0.3mg/l in drinking water sample from the three boreholes from Robe town and Robe main reservoir.
- TDS was found to have a positive correlation with copper, sulfate, temperature and fluoride concentration of water samples from different sources in the study area.
- Turbidity was found positively correlated with nitrate and manganese concentration of water samples from different sources in the study area.

***Moringa Stenopetala* seed powder for turbidity, nitrate, and Hardness**

- The *M. stenopetala* seed powder was found effective for removal of turbidity, hardness, and nitrate in water samples.

Recommendations

The concerned sectors (Ministry of Health, Ministry of Water Resources, Non-Governmental Organizations involved in water and sanitation activities and the beneficiaries) must increase their effort in spring protection, monitoring and evaluating the existing facilities, including regular check up of its bacteriological safety, and undertaking source maintenance if needed.

- Promoting use of safe water storage and low-cost effective water treatment methods at the household level in order to avoid the possibility of contaminations
- Increased emphasis on improved basic sanitation and reducing environmental contamination should be made by promoting Total Sanitation Approach which aims to achieve universal access and use of toilets and the elimination of open defecation in the communities.
- Promoting incremental sanitation (sanitation ladder) which initially starts with simple pit latrine, then upgrading to ventilated improved pit latrine (VIP) and pour-flush and then later to a severed flush toilet.
- Promoting proper household solid waste management during onsite handling, storage and collection and minimizing the adverse effects caused by improper practices.
- Promoting integrated solid waste management (ISWM) by waste recovery options, particularly the use of organic waste materials for making compost for home gardening.
- Promoting door-to-door collection systems by private or community-based waste collectors which could contribute to the improvements in domestic solid waste management.
- Crude dumping and open burning of waste should be completely avoided by encouraging safe solid waste collection and disposal methods.
- Strengthening hygiene education especially targeting communities and households on the practices of basic sanitation, waste disposal, and good hygiene practices.

- Strengthening hygiene promotion programme through all possible media, materials, and methods, particularly using the most popular source of hygiene information in the community including health extension workers; mass media such as television and radio; community groups; health institutions and schools.
- Since *Moringa stenopetala* seed powder was found in the locality and has no identified health and environmental problems so far Hence, treatment of water using *Moringa stenopetala* seed seems appropriate. However; water treatment using *Moringa stenopetala* seed has not yet been practiced to date.
- Awareness on the water clarification potential of *M. stenopetala* seed powder should be made in the country especially in areas where this magic tree available in order to familiarize with its water treatment potential.
- Organizations, which are responsible for conventional water treatment plant, should see alternative natural coagulants such as *Moringa stenopetala* seed powder for drinking water treatment.

References

- AACCSA(2011). 'Country Information' Available at <http://www.addischamber.com/aaccsa/countryinfo/country.php> [Accessed 10 June 2014]
- Abatneh, Y., Sahu, O., & Yimer, S. (2014). Purification of drinking water by low cost method in Ethiopia. *Applied Water Science*, 4(4), 357–362.
<https://doi.org/10.1007/s13201-013-0151-9>
- ADF (2005). Rural water supply and sanitation program appraisal report: Ethiopia. Infrastructure department North, East, and South, ONIN.
- ADWG (2002), Microbiological Quality of Drinking Water in Australia, Vol.1 2ed.
- Agbogun Vincent N., Veronica J. Umoh, Charles A. Okuofu, Stella I. Smith and Joseph B. Ameh (2006). Study of the bacteriological and physico-chemical indicators of pollution of source waters in Zaria, Nigeria. *African Journal of Biotechnology*; 5 (9), 732-737.
- Alaci A. and Alehegn, E. (2009). Infrastructure provision and the attainment of Millennium Development Goals (MDG) in decentralized systems of Africa; Experiences from Ethiopia and Nigeria. Abuja, Nigeria.
- AMCOW (2010). African Minister Counsel On the water,
- Bartlett, S. (2003). Water, sanitation and urban children: the need to go beyond "improved" provision. *Environment and Urbanization* 15(2):57-70.
- Benefield, D.L., Judkins, F.J. and Weand, L.B. (1982). Process chemistry for water and wastewater treatment. New Jersey: Prentice-Hall.
- Beyene, A ; Hailu, T; Faris, K; and Kloos, H (2015). Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era *BMC Public Health* (2015) 15:451 DOI 10.1186/s12889-015-1804-4.

- Bitton, G. (1999) Wastewater microbiology, 2 Edition. Canada, Wiley – Liss, Inc.
- Brian O. (2002). Water Testing Bacteria, Coliforms Nuisance Bacteria, Viruses, and Pathogens in Drinking Water. Center for Environmental Quality, Environmental Engineering, and Earth Sciences. Wilkes University. Web Design pros.net.Calow, R., MacDonald, A., and Cross, P. (2012). ‘Corruption in rural water supply in Ethiopia’, in J. Plummer (ed.), Diagnosing Corruption in Ethiopia: Perceptions, realities and the way forward for key sectors, chapter 4, World Bank, Washington D.C.
- Central Statistics Authority (CSA) and ORC Macro (2011). Ethiopian Demographic and Health Survey. Addis Ababa, Ethiopia: CSA and ORC Macro.
- Central Statistics Authority (CSA) and ORC Macro (2014).Ethiopian Demographic and Health Survey. Addis Ababa, Ethiopia: CSA and ORC Macro.
- Chan C., Zalifah M.K.and Norrakiah A.S. (2007) Microbiological and physicochemical quality of drinking water. The Malaysian Journal of Analytical Science, 1(2): 417-419.
- Choffnes E.R. and Rapporteurs A.M (2009). Forum on microbial threats; Institute of Medicine. The National Academies, Advisors to the Nation on Science, Engineering, and Medicine. ISBN: 0-309-13873-6, PP. 76.
- Christa L, Walker L, Perin J, Martin J, Bochi-Pinto C, Robert E.(2012) Diarrhea incidence in low- and middle-income countries in 1990 and 2010: a systematic review. BMC Public Health **12:220**.
- Christophe Bosch *etal* (2001). Water, Sanitation, and Poverty.
- Clasen TF, Boston K, Schmidt WP, Boisson S, Fung ICH, Jenkins MW, Scott B, Sugden S and Cairncross S. 2010. Interventions to improve disposal of human excreta for preventing diarrhea: Cochrane database of systematic reviews. London: The Cochrane Collaboration. Published by John Wiley and Sons, Ltd.
- Cleophace J, (2007).Urban Environmental Infrastructure in Kigali City Rwanda; Challenges and Opportunities for Modernized Decentralized Sanitation Systems in Poor Neighborhoods. Wageningen University Netherlands.

- Collick, A. (2008) Community Water Use in the Yeku Watershed and Hydrological Modeling in Watersheds of the Upper Nile Basin, Northern Ethiopia: Dissertation, Cornell University, Ithaca, NY, USA.
- Corcoran, E (2010). The central role of wastewater management in sustainable development – A rapid response assessment, United Nations Environment Programme, UN-HABITAT and GRID-Arendal, www.grida.no, 2010.
- CSA (2007). The Population and Housing Census of Ethiopia.
- Curtis and Cairncross(2000). The F-diagram for fecal-oral disease transmission.
- Dagnew, T., Assefa, D., Abera, G., Woldemariam, G., Solomon, F., Oliver, S. (2010). Rapid assessment of drinking water Quality in the federal Democratic republic of Ethiopia. World Health Organization, Geneva, Switzerland.
- Demeke A. (2009). Determinants of household participation in water resource management; Achefer woreda, Amhara region, Ethiopia. Master's thesis Integrated Agriculture and Rural Development. Cornell University, Ithaca NY USA.
- Desalegn A (2013). Assessment of Water Handling Practices among Rural Communities of Dire Dawa Administrative Council, Dire Dawa, Ethiopia. Sci. Technol. arts Res. J., 2(2): 75-82.
- Development Experimental Station (TRIADES), Technical Bulletin No. 2Richards and Jamie B, 1996.
- DHV, C. W. (2003). National Water Supply and Sanitation Master Plan Framework. Addis Ababa: DHV/MoWR.
- Diaz, A., Rincon, N., Escorihuela, A., Fernandez, N., Chacin, E. and Forster, C.F. (1999). A preliminary evaluation of turbidity removal by natural coagulants indigenous to Venezuela. Process Biochemistry, 35: 391–395
- Doria M.D.F (2010). Factors influencing public perception of drinking water quality. Water policy 12:1-19.
- EDHS, (2014).Ethiopian Demographic and Health Survey.

Edwards. S., Mesfin Tadesse, Sebsebe Demissew and Hedberg I., (2000). Flora of Ethiopia and Eritrea, Volume 2, Part 1: Magnoliaceae to Flacourtiaceae. Addis Ababa, Ethiopia.

ELE International.(2003) Paqualab water quality laboratory Portable drinking water quality testing system.

Emerson (2000) 'Review of the evidence base for the 'F' and 'E' components of the SAFE strategy for trachoma control'. Tropical Medicine & International Health (8): 515-27.

Engels, J. H. (1991). Konso agriculture and its plant genetic resources. Addis Ababa: Cambridge University Press.

Environmental Health Project. (2004a). Assessing hygiene improvement: Guidelines for household and community levels. Washington, DC: United States Agency for International Development (USAID) Environmental Health Project (EHP).

Fawell J (2006). Fluoride in drinking water. London, IWA Publishing on behalf of the World Health Organization (WHO Drinking-water Quality Series.

FDRE (2017). Voluntary National Reviews on SDGs of Ethiopia: Government Commitments, National Ownership and Performance Trends National Plan Commission. Addis Ababa

Federal Democratic Republic of Ethiopia National Hygiene and Sanitation Strategy Ministry of Health, (2005), Ethiopia Addis Ababa.

Fewtrell L, and Colford J. (2004). Water, Sanitation, and Hygiene: Interventions and Diarrhea a Systematic Review and Meta-analysis. The International Bank for Reconstruction and Development.

Frank van Steenberg, Redda Tekle Haimanot, Aschalew Sidelil (2010). High Fluoride, Modest Fluorosis: Investigation in Drinking Water Supply in Halaba (SNNPR, Ethiopia) Journal of Water Resource and Protection, 2011, 3, 120-126 doi:10.4236/jwarp.2011.32014.

Franceys, F, J. Pickford, and R. Reed .(1992). A Guide to the development of on-Site sanitation. Geneva: World Health Organization.

Garcia-A. and Servais (2006). Respective contribution of Point and non-Point Sources of E. Coli and Enterococci in A Large Urbanized Watershed (The Seine River, France).

Gassenschmidt, U., Jany, K. K., Tauscher, B., & Niebergall, H. (1995). Isolation and characterization of a flocculating protein from *Moringa oleifera* Lam. *Biochimica et Biophysica Acta (BBA) - General Subjects*, 1243, 477–481.

[https://doi.org/10.1016/0304-4165\(94\)00176-X](https://doi.org/10.1016/0304-4165(94)00176-X)

Getnet K. (2008). Physico-chemical and Bacteriological Drinking Water Quality Assessment of Bahir Dar town water supply from source to yard connection (North-Western Ethiopia). M.Sc Thesis, Addis Ababa University, Addis Ababa.

Gleick P , (2002). *Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020* Pacific Institute for Studies in Development, Environment, and Security.

Gupta, A. and Chaudhuri, M. (1992). Domestic water purification for developing countries. *J. Water SRT-Aqua*, 41 (5) pp 290-298. Gupta 2009.

HACH (2010). DR/2010 spectrophotometer instrument manual. HACH Company, Colorado, USA.

Harvey, P.A. (2008) *Poverty Reduction Strategies: Opportunities and threats for sustainable rural water services in Sub-Saharan Africa*. *Progress in Development Studies*, 8(1): 115-128.

Haworth (1996). A survey of pollution indicator bacteria in water wells of Rutherford Country, Tennessee. *Journal of the Tennessee Academy of Science*. 56(3), 73-75.

Health Canada (2012). *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity*. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. (Catalogue No H144-9/2013E-PDF).

Howard, G (2003). *Domestic water quantity, service, level and health*. Geneva: World Health Organization.

Howard, G. (2002) Healthy villages: A guide for communities and community health workers. 2002. Geneva: World Health Organization (WHO).

Hunter PR, MacDonald AM, Carter RC (2010). Water Supply and Health. PLoS Med 7(11).

Hutton G, Haller L. (2004). Evaluation of the costs and benefits of water and sanitation improvements at the global level. Geneva: World Health Organization.

Hutton, G., Haller, L. and Bartram, J. (2007). 'Global cost-benefit analysis of water supply and sanitation interventions' Journal of water and health.05(4). 481-502.

International Federation of Red Cross and Red Crescent Societies (2007).

Jahn, S. A. A. (1991). The traditional domestication of a multipurpose tree *Moringa stenopetala*. *Ambio*, 1, 244–247.

Jahn, S.A.A., (1984). The effectiveness of traditional flocculants as primary coagulants and coagulant aids for the treatment of tropical raw water with more than a thousand-fold fluctuation in turbidity. *Water Supply*, 2(3/4) Special Subject pp 8-10.

Jennifer, S. (2015). Researchers study inexpensive process to clean water in developing nations. Nigeria: Development Council in Abuja.

JMP (2010). Progress on sanitation and drinking water 2010 update.

Kaggwa, R.C., Mulalelo, C.I., Denny, P., Okurut, T.O. (2001). The impact of alum discharges on a natural tropical wetland in Uganda. *Water Res*;35(3): 795-807.

Karanth, K.R. (1987). Groundwater Assessment Development and Management Tata McGraw Hill publishing company Ltd., New Delhi, pp 725-726.

Kassahun B. (2008). Assessment of physicochemical and Bacteriological Quality of Drinking Water in the Central Rift valley System, Ziway Town Oromia Region, Ethiopia. M.Sc Thesis, Addis Ababa University, Addis Ababa.

Katharina Diouf Patrik Tabatabai, Jochen Rudolph and Michael Marx. (2014) . Diarrhea prevalence in children under five years of age in rural Burundi: an

assessment of social and behavioral factors at the household level. *Glob Health Action* 7: 24895.

Kegley, S.E. and Andrews, J.(1997). *The Chemistry of Water*. Library of Congress Cataloging in Publication Data. University Science Books, Sausalito, California. 48-51.

Keller B. (2009). *Environmental Science Earth as Living Plant*. 7th ed., John Wiley & Sons Inc., New York, pp. 467-483.

Kitaw Y. (1980). Water supply in a small village in Ethiopia, Kidame Gebeya. *Ethiopian Med J*.18 (4): 165-169.

Korkeakoski,(2006). A guide to sanitation and hygiene for those working in developing countries.Global dry toilet club. FinlandKravitz J, 1999.

Kumie, A. & Ali, A. (2005).An overview of environmental health status in Ethiopia.’ *Ethiopia Journal of Health Development*. 19 (2). 90-102.

Lee, L.Y., Lu, C. and Kung S.L.(2003). Spatial Diversity of Chlorine Residuals in a Drinking Water Distribution System. *J. Environ. Eng.* 130, 1263–1268.

Lehtola, M.J., Miettinen, I.T.and Martikainen P.J (2002). Biofilm Formation in Drinking Water Affected by Low Concentrations of Phosphorus. *Can. J. Microbiol.* 48, 494–499.

Lick, W. (2008). *Sediment and contaminant transport in surface waters*. CRC Press. 404pp.

Lioud, BA (1992). Checklist of hazards: World health organization. July&august.1&7

Luby S.P (2005). Clean Hands Reduce the Burden of Disease cited Pitet D. *The Lancet*, Volume 366, Issue 9481, Pages 185 - 187, 16 July.

Mara, D., Lane, J., Scott, B., and Trouba, D. (2010). ‘Sanitation and Health’, *PLoS Med* 7(11): e100363.

Mark. (1998). Research on applied uses of *Moringa stenopetala*. Ethiopian Tree Fund Foundation.

Mebratu J. (2007). Assessment of Physico-chemical Microbiological Quality of Rural Drinking Water Supply at the Sources in Menge Woreda, Benshagul-Gumze Regional State, Ethiopia. M.Sc Thesis, Addis Ababa University, Addis Ababa.

Meinzing F, Oldenburg M and Otterpohl R. (2008). No waste, but a resource: Alternative approaches to urban sanitation in Ethiopia; Institute of Wastewater Management and Water Protection, Hamburg University of Technology, Germany.

Mekasha A, and Tesfahun A. (2003). Determinants of diarrheal diseases: a community-based study in urban South Western Ethiopia. East Afr Medical J, 80(2):77-82.

Mengstayehu, B. (2007). Assessment of physico-chemical microbiological quality of rural drinking water supply at the sources and selected communities of Akaki-Kalit Sub-City, Addis Ababa City Administration. M.Sc Thesis, Addis Ababa University, Addis Ababa.

Mertens, TE. (1990). Determinants of water quality, availability and use in Kurunegala Srilanka. Tropical medicine and Parasitology 41(1): 89&97.

Miettinen, IT. Vartiainen, T and Markikainen PJ (1997). Phosphorus and bacterial growth in drinking water. Appl. Environ. Microbiol. 63 (8), 3242–3245.

Ministry of Health (2011). Hygiene and environmental health, part 1: Blended learning.

Ministry of Water Resources (MoWR) (2002). Ethiopian Water Resources Management Policy, FDRE, Module for the health extension programme. Addis Ababa: Ministry of Health (MoH).

MOFED (2010). MDGs report: Trends and Prospects in meeting MDGs in 2015. Addis Ababa: Federal Ministry of Finance and Economic Development; 2010.

MoH & MoWE (2013). Trends in access to improved water sources coverage, in Ethiopia (1997-2012 GC)

- MoH.(2011). National Hygiene and Sanitation Strategic Action Plan for Ethiopia 2011–2015, Final Draft, FDRE, Addis Ababa.
- Mohammed A I (2011). Assessing environmental sanitation in the urban setting of Dukem town, Ethiopia. Master Thesis. University of South Africa
- Morton, J. F. (1991). The horseradish tree, *Moringa pterygosperma* (Moringaceae): A boon to arid lands? *Economic Botany*, 45(3), 318–333.
<https://doi.org/10.1007/BF02887070>.
- Mumbai M. Tyafa, Z., Malaka, Brouckaert, B.M., and Obi C.L. (2006). Safe drinking water still a dream in rural areas of South Africa: The Eastern Cape Province. *J. of Water Science Res. and Technol.*32 (5), 208-213.
- Murphy S. (2007b). General Information on Phosphorus. Water Quality Monitoring. City of Boulder/USGS.
- Murphy S.(2007a).General Information on Phosphorus. Water Quality Monitoring. City of Boulder/USGS.
- Muyima N. and Ngcakani F. (1998). Indicator bacteria and regrowth potential in the drinking water of Alice. *J. Biochem and Microbial.*24 (1), 29-34 NGL, 2002.
- Nold (2008). Rapid Microbial Monitoring Methods. The Status Quo International Water Associations Blue Pages.
- Nuru F. (2012).Managing water for inclusive and sustainable growth in Ethiopia: key challenges and priorities’, Background Paper for the European Report on Development 2011/12, ODI in partnership with the Deutsches Institut für Entwicklungspolitik (DIE) and the European Centre for Development Policy Management (ECDPM).
- OECD (2012). Environmental Outlook for 2050, OECD, Paris.
- Okuda, T., Baes, A. U., Nishijima, W., & Okada, M. (2001). Isolation and characterization of coagulant extracted from *Moringa oleifera* seed by salt solution. *Water Research*, 35(2), 405–410.

Omsa, R. E., (2005). The impact of water conflicts on pastoral livelihood: The case of Wajir District in Kenya. Winnipeg, iisd., Tokyo.

OXFAM (2004). Oxfam-Delagua Portable Water Test Kit. User Manual-24. Robens Center for Public and Environmental Health. University of Surrey, Guildford, Gu25XH, United Kingdom. Phiri et al., 2005.

Pickering, A. J., and Davis, J. (2012). Freshwater Availability and Water Fetching Distance Affect Child Health in Sub-Saharan Africa. *Environmental science & technology*, 46(4), 2391- 2397. doi: 10.1021/es203177v.

Postnote (2002). 'Access to sanitation in developing countries' Parliamentary office of science and technology.

Prasad, R.K. (2008). Color removal from distillery spent wash through coagulation using *Moringa oleifera* seeds: Use of optimum response surface methodology. *J. of Hazard. Mater.* In press.

Prüss-Üstün, A, Bos, R, Gore, F & Bartram, J. (2008). Safer water, better health: costs, benefits, and sustainability of interventions to protect and promote health. Geneva: World Health Organization (WHO) Public Health Protection, 2000.

Rams, J., (1994). *Moringa* a highly nutritious vegetable Tree, Tropical Rural and Island/atoll.

Reda AH (2016). Physico-Chemical Analysis of Drinking Water Quality of Arbaminch Town. *J Environ Anal Toxicol* 6: 356. doi:10.4172/2161-0525.1000356.

Ring, S. (2003). Introduction to Microbial Safety of Drinking Water: Drinking Water Academy USEPA.

RWSN (2008). Sustainable Rural Water Supplies. Rural Water Supply Network, St. Gallen.

Sartaj, A. (2013). "Drinking Water Quality Assessment in Some Selected Kebeles of Nagar Valley Gilgit-Baltistan, Pakistan," *Journal of Chemical, Biological and Physical Sciences* 3 (1): 567-574.

- Seifu, E. (2015). Actual and potential applications of *Moringa stenopetala*, underutilized indigenous vegetable of Southern Ethiopia: A review. *International Journal of Agricultural and Food Research*, 3(4).
- Shears P, Hussein MA, Chowdhury AH & Mamun KZ (1995). Water sources and environmental transmission of multiply resistant enteric bacteria in rural Bangladesh. *Annals of Tropical Medicine and Parasitology* 89, 297–303.
- Short, K. (2006). Review of hand washing programmes. Delft: IRC International Water and Sanitation Centre.
- Sijbems W. (1989). What Prices Water? User Participation in Paying for Community Based Water Supply with Particular Emphasis on Piped System, The Hague, and the Netherlands.
- Skoog, A.D., West, M.D. and James Holler, F. (1997). *Fundamentals of analytical chemistry*, 7th Edition. Orlando: Harcourt.
- Sobsey, M.D. (2002). *Managing Water in the Home: Accelerated Health Gains from Improved*. WHO, Geneva.
- Song, Z., Williams, C.J., and Edyvean, R.G.J. (2004). Treatment of tannery wastewater by chemical coagulation. *Desalination*, 164: 249–259.
- Steve H, (2004), *American University Complex Emergencies Reader*, fall 2003, p. 608. Sphere p. 71.
- Sutton, S., Dominic. M (1989). Household water quality in rural Zambia. *Water Lines* 8(1): 20-21.
- Swerdlow DL, Mintz ED, Rodriguez M et al. (1992). Waterborne transmission of epidemic cholera in Trujillo, Peru: lessons for a continent at risk. *Lancet* 340, 28–33.
- Tadesse Sisay, Abebe Beyene, Esayas Alemayehu, Assessment of drinking water quality and treatment plant efficiency in Southwest Ethiopia, *J. Env. Sci. Pollut. Res.* 3(3) (2017) 208–212.

- Teferi , A (2007). Assessment of knowledge and hygienic practices towards bacteriological quality of drinking water at Dobe Toga Kebele, Shebedino Woreda, SNNPR. M.Sc thesis.
- Teklu, M and Kebede, F (1998). Survey on practice of water handling and level of contamination in Jimma town. *Ethiopian Journal of Health Science* 8(1): 29&34. Temesgen, 2009.
- Thewodros B, Seyoum L (2016) Water Supply and Health: Drinking water and Sanitation Coverage in Ethiopia 1990 - 2015 Review. *International Journal of Environment, Agriculture, and Biotechnology (IJEAB)*. Vol-1, Issue-1.
- Thomas, C , and Cairncross, S. (2004). Household water management: refining the dominant paradigm. *Tropical Medicine and International Health* 9(2):187-191.
- Tiku S, Legesse W and Kebede F (2003). Factor affecting water quality from source to home in Tehuledere woreda, Northeast Ethiopia. *Ethiopian Journal of Health Science* 13 (2): 94&106.
- Tucker, J. and Yirgu, L. (2011). ‘Water in food security assessment and drought early warning: experience from sub-Saharan Africa with a special focus on Ethiopia’, RiPPLE Working Paper 21, RiPPLE, Addis Ababa.
- Tya, T., Umaru, A., Barmamu, B. (2012). “Bacteriological analysis of hand dug-wells water in Demsa local government area, Nigeria.” *International referred Journal of Engineering and science* 1(4): 28-31.
- Udaybir Singh Mann, Arvind Dhingra, Jaswinder Singh (2014). Water pollution: causes, effects, and remedies. *International Journal of Advanced Technology in Engineering and Science* Volume No.02, Issue No. 08.
- UN (2014).The Millennium Development Goals Report, 2014.
- UN The Millennium Development Goals Report (2014). Progress on Drinking Water and Sanitation. 2013 update. UNICEF, WHO, March 2013.
- UN Water (2013). Factsheet on Water and Gender.

UNDP, (2006). Human Development Report beyond Scarcity: Power, poverty and the global water crisis.

UNEP/GRID-Arendal (2000). Freshwater Stress. UNEP/GRID-Arendal Maps and Graphics Library.

UNESCO (2009). Water in a Changing World. The United Nations World Water Development Report 3. UNESCO, Paris.

UNESCO-WWAP. (2006). Water a shared responsibility, the UN World Water Development Report 2. New York, UNESCO-WWAP/Berghahn.

UN-HABITAT, (2006). Options for Small Urban Centers in Developing Countries' (or nearly a third of the world's population).

UN-HABITAT,(2003).United Nations Human Settlements Programme: Improving the lives of 100 million slum dwellers; towards the Millennium Development Goals, Nairobi Kenya.

UNICEF (2008). Promotion of Household water treatment and Safe Storage in UNICEF Wash Programmes.

UNICEF and World Health Organization (2012). Progress on Drinking Water and Sanitation: 2012 Update WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation.

UNICEF and World Health Organization (2015). Progress on sanitation and drinking water 2015 update and MDG assessment. World Health Organization, Geneva.

UNICEF, (2006). Meeting the MDG Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade, Switzerland.

UNICEF/WHO (2009). **Diarrhea: Why Children are Still Dying and What can be Done**. New York: UNICEF.

UNICEF/WHO (2013). Progress on Drinking Water and Sanitation. UNICEF, WHO, 2013 update.

United Nations Children's Fund. (2006). Progress for children: A report card on water and sanitation. New York: UNICEF.

United Nations Children's Fund. (2008). UNICEF handbook on water quality. New York.

USAID (2013-2018). Water and development strategy

USNRC (2006). Fluoride in drinking water: A scientific review of EPA's standards. Washington, DC, United States National Research Council, National Academies Press.

Volk, C.J., Hofmann. Chauret, C., Gagnon, G.A., Ranger, G. and Andrews, R.C. (2002). Implementation of Chlorine Dioxide Disinfection: Effects of the Treatment Change on Drinking Water Quality on Full –Scale Distribution System. J. Environ. Eng. Sci. 1,323-330.

WASH Field Note (2017). Progress on CLTSH in Ethiopia ; Findings from a National Review UNICEF for every child.

WHO (2000). WHO Seminar Pack for drinking water quality WHO.

WHO (2004). Water Treatment and Pathogen Control: Process Efficiency in Achieving Safe Drinking Water. Edited by Mark W LeChevallier and Kwok-Keung Au.

WHO (2004a). Water treatment and pathogen control. Process efficiency in achieving safe drinking water. IWA Publishing, Alliance House, 12 Caxton Street, London SW1H0QS, UK.

WHO (2008). Guidelines for Drinking-Water Quality, incorporating the first and second addenda, World Health Organization, Geneva Switzerland, volume 1.

WHO (2008). Guidelines for drinking water quality. 3rd Edition. Incorporating the 1st and 2nd Addenda, Volume 1, Recommendations. Geneva: WHO.

WHO (1997). Guideline for drinking water quality, Vol. III.

WHO (2003). Total dissolved solids in drinking water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization (WHO/ SDE/WSH/03.04/16).

WHO (2005). Guidelines for drinking water quality, 2nd edition, Health Criteria, Vol.3. World Health Organizations Switzerland, Geneva.

WHO (2006). Guidelines for Drinking-water Quality, 1stAddendum to the 3rded., Volume 1: Recommendations, World Health Organization, Geneva.

WHO (2010). UN-Water Global Annual Assessment of Sanitation and Drinking-Water (GLAAS) 2010: targeting resources for better results. World Health Organization, Geneva)

WHO (2011). Manganese in drinking water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization.

WHO) and UNICEF (2017). Progress on Drinking Water, Sanitation and Hygiene Update and SDG Baselines. Geneva:), 2017. Licence: CC BY-NC-SA 3.0 IGO.

WHO/UNICEF (2011). Joint Monitoring Program for Water Supply and Sanitation (JMP) Drinking Water Equity, Safety and Sustainability: Thematic report on drinking water 2011.

WHO/UNICEF JMP, (2015) Estimated trends of use improved drinking water sources in Ethiopia. Source: 2013-2015

WHO/UNICEF. (2012). Fast facts; water sanitation hygiene, WHO/UNICEF joint monitoring report 2012 Retrieved from http://www.who.int/water_sanitation_health/monitoring/jmp2012/fast_facts/en/

World Bank (2005). The handwashing handbook – A guide for developing a hygiene promotion programme to increase handwashing with soap. Washington DC: World Bank.

World Health Organization (2004). “Costs and benefits of water and sanitation at the global level”

World Health Organization (2004). Guidelines for Drinking Water Quality: 3rd Edition, Vol. 1 – Recommendations. WHO, Geneva.

World Health Organization (WHO) and United Nations Children’s Fund (UNICEF) (2012). Progress on Sanitation and Drinking Water: 2012 Update, WHO Press, Geneva.

World Health Organization and UNICEF (2013). Progress on sanitation and drinking water 2013 update. WHO/UNICEF joint monitoring program for water supply and sanitation.

World Health Organization Regional Office for Africa. (2009). Health security through healthy environments. Proceedings of First Inter-Ministerial Conference on Health and Environment in Africa by the World Health Organization and the United Nations Environment Programme in partnership with the Government of Gabon, 26-29 August 2008.

WSP-EPA (2008). ‘Economic Impacts of Sanitation in the Philippines a five-country study conducted in Cambodia, Indonesia, Lao PDR, the Philippines and Vietnam under the Economics of Sanitation Initiative.

Annexes

Questionnaire

Questionnaire on Sanitation and water handling practices of communities of Robe and Ginnir Towns in Bale Zone, Oromia Region South East Eth

The ethical approval and Permissions were secured from my Supervisor, *Oromia Region Bale Zone water supply and sanitation Office*, and *from municipality of the towns for public water source samples and consent from private water source owners is obtained before sample collection*; Respondents and officials were briefed about the purpose, procedure of the study and the confidentiality of the information and verbal consent were obtained from each respondent.

Informed consent from each study subject is obtained after giving a clear explanation on the purpose of the study. The Purpose of these Questionnaires is to collect data on Sanitation and water handling practices of communities of Robe and Ginnir Towns in Bale Zone Oromia Region South East Ethiopia in order to alleviate problems regarding drinking water Quality sanitation and hygiene. - So you are kindly requested to provide useful information to help the research work succeed.

HOUSEHOLD IDENTIFICATION		
Date of interview: ____/ ____/ ____		Time started
Region: _____	Zone: _____	Woreda: _____
Town: _____	Kebele: _____	House number: _____

NO.	QUESTIONS	CODING CATEGORIES	SKIP
SOCIO-DEMOGRAPHIC AND ECONOMIC DATA			
101	Age of the respondents in year		
102	Sex	1. Male 2. Female	
103	Religion	1. Orthodox 2. Protestant 3. Muslim 4. Others (specify)	
104	Educational level of the Respondent	1. Illiterate 2. Read and write 3. Primary 4. Secondary and above 5. Other(specify)	
105	Number of person in the household		
106	Number of children under 5 in the household		

WATER HANDLING PRACTICES			
201	What is the main source of water for the household?	1. Protected spring 2. Unprotected spring 3. Rainwater 4. Tanker truck 5. Surface water (river /dam) 6. Lake/pond/stream/canal/irrigation	

		channel 7. Others(specify) -----	
202	How much is your water consumption	1. 1-5 jerricanes ---2. 6-10 jerricanes 3. >10 jerricanes	
203	Who usually goes to your main water source to fetch the water for your household?	1. Housewives 2.house maid 3. children's 4. other (specify)-----	
204	Types of collection container (observe)	1. Clay pots---- 2.Jerricans----- 3..Plastic buckets-----4.Metal buckets--- -22.other/ specify-----	
205	Is the water collection container has cover material during transport? (Observe)	1.yes ----- 2.no-----	
206	Do you wash your hand before water collection	1.yes ----- 2.no-----	
207	Do you wash the container before refilling?	1.yes ----- 2.no-----	
208	Do you separate drinking water from other household use (such as washing of utensils & clothes)?	1.yes ----- 2.no-----	
209	How many times do you collect water? Frequency of water collection	1.every another day---2.every day- 3.twice a day---22.other/specify-	
210	Do you store water in the home?	1.yes---2. no-----	
211	Do you have a separate storage container?	1.yes ----- 2.no-----	
212	Types of storage container (observe)	1. Clay pots---- 2. Jerricans--- 3.Plasticbuckets---4.Metal buckets---- 22.other/ specify-----	
213	Do you wash water storage container before storing water	1.yes ----- 2.no-----	

214	Do you cover the storage containers	1. Yes-----2. no-----	
215	What methods do you use to withdraw water from container	1.pouring----- 2.dipping-----	
216	Are the utensils used to draw water from the container with a handle?	1.yes ----- 2.no-----	
217	Where do you put water drawing utensils?	1.Table or shelves--- 2.Inside the container----- 3. Storage cover----4. Hang on well- 5.Floor----22.other/ specify-----	
218	Do you wash your hands before drawing water from the storage container?	1.yes ----- 2.no-----	
219	Is the area around the storage container sanitary?(observe)	1.yes ----- 2.no-----	
220	Is there a possibility for animals to reach the storage container	1.yes ----- 2.no-----	
221	For how long do you store the water the water will be stored in the container	1.for 1 day and below----- 2. a day and above -----	
222	How much time do you need to fetch water?	-----	
223	Do you use the cup for another purpose? (what type of cup)	1.yes 2.no	
224	While you are collecting water from the tap, is there contact of the hands with water?	1.yes ----- 2.no-----	
225	The water collected from the tap transported to your house in covered containers?	1.yes ----- 2.no-----	
226	In your house, is the water for drinking is stored in a separate container away from water intended for other purposes?	1.yes ----- 2.no-----	

227	The drinking water that you take from the storage containers has no contact with your hands?	1.yes -----2.no-----	
228	Do you clean your water collection containers every day?	1.yes -----2.no-----	
229	Do you treat your water in any way to make it safe to drink?	1. Yes, 2. No 3.Don't know	
230	What do you usually do to the water to make it safer to drink? Anything else? Record all mentioned	1. Boil-----A 2. Add bleach /chlorine-----B 3. Strain through a cloth-----C Use water filter (cream/sand/composite/etc) -----D 4. Solar disinfection-----E 5. Let it stand and settle-----F Other----- (Specify)-----	
231	How does your household primarily dispose of household waste?	1. Collected by municipality-----1 2. Collected by private Establishment-2 3. Dumped in street /open space-----3 4. Dumped in river----- 4 5. Burned -----5 6. Other----- (specify)-6 Don't know-----8	
232	How far is the water source from your household (estimated distance)	-----meters	
233	How do you view the location of the water source with respect your household?	1. Very inconvenient 2. Inconvenient 3. Convenient 4. More Convenient 5. Very Convenient	
234	How much water on average did you	-----liters	

	collect every day for the household use?		
235	Are you satisfied with this amount of water available to your household daily for drinking, cooking, and sanitation?	1. Not satisfied with all 2. Somewhat dissatisfied 3. Partially satisfied 4. Satisfied 4. Highly satisfied	
236	During the past year, how frequently have you used the water from the source for generating income (an example might be for vegetable production)?	1. Not at all 2. Sometimes 3. Often 4. Very often	
237	How would you rate the degree of your participation during the project implementation process (in the time of the construction of the water source)?	1. None at all 2. Low 3. Fair 4. Very good 5.Excellent	
238	If you have participated, in what aspect was your contribution? (indicate one or more based on your contribution)	1. Providing labor 2. Providing cash 3. Providing local materials such as wood In management and as a member of committees (decision making), other (please specify)	

SANITATION AND HYGIENE PRACTICES OF CONSUMERS			
301	Do you have a latrine?	1.yes -----2.no-----	If no go to Q 302
302	If a latrine is not available where the families dispose their feces?	1.Open field-----2.farmland----- 3.Other (specify)----	
303	What type of latrine do you have?	1. Pit 2. VIP 3.Water Carriage	

		4.Others (specify)	
304	Utilization of latrine	1. Always----2. sometimes---- 3. never at all-----	
305	Sanitation of the latrine	1. Good -----2. poor -----	
306	Do you wash your hands after visiting the latrine?	1.yes----- 2.no-----	
307	If there is water source near the latrine how much is the distance	1.1-10meter 2. >10metre	
308	Do you store refuse in your home?	1. Yes----2. No-----	
309	Where do you dispose the refuse? (observe)	1.Pit---- 2.Open field---- 3.water body----4.Burning----5.used as fertilizers----- 22.Other (specify) -- -	
310	How do you store the refuse?	1.Using covered material----- 2. using uncovered material 3. Pit 22. Other/specify....	
311	Do humans and animals live in the same house?	1.yes 2.no	
312	Is there any person who suffered from diarrhea in the last two weeks?	1.yes 2.no Specify age----- -	
313	Is there soap or detergent or ash near the hand washing place? (observe)	Yes -----1 No ----- 2	
314	Do you have 5 children?	Yes -----1 No -----2	
315	What was done to dispose of the stool of the youngest child?	Child used toilet/latrine -----1 Thrown into garbage ----- 2 Buried ----- 3 Left in the open ----- 4 Other, specify -----99	

316	If they do not have toilet facility, what is the reason?	Lack of money-----1 Lack of space ----- 2 Lack of permission for construction -3 The house is rented ----- 4 Others, specify ----- 99	
317	Do you have a bar of soap for hand washing in your household today?	Yes -----1 No -----2	
318	Have you used soap for washing during the past 24 hours?	Yes ----- 1 No ----- 2	
319	If you used soap during the last 24 hours, what did you used it for (Circle all the replies)	Washing clothes -----1 Washing my body-----2 Washing my children's body --3 Washing my children's hand ---4 Washing my hands -----5 Other, specify -----99	
320	If for washing hands is mentioned, Robe what was the occasion, but do not read the answer {circle all that apply}	Washing hands after defecating -1 Washing hands after cleaning child - 2 Washing hands before feeding children 3 Washing hands before preparing food--4 Washing hands before eating -----5 Washing hands after eating----6 Other, specify ----- 99	
321	When is it important to wash hands? {circle all replies}	Before preparing food or cooking -1 Before eating ----- 2 Before feeding children -----3 After defecating -----4	

		After cleaning children's faces ---- 5 After eating food -----6 Other, specify-----99	
322	Where did you take bath?	I have shower in my house -----1 I used neighbor's shower ----- 2 I have bath -----3 I used public bath ----- 4 I used bucket -----5	
323	How often do you take shower?	Every day-----1 As needed ----- 2 Every week ----- 3 Every two week -----4 Other, specify -----99	

Afaan Oromo version of questionnaire

Gaaffiilee dhimmaa qulqullinaa fi haala qabinsa bishaanii irratti qophaa'ee kan magala Roobee fi Gindhiir irratti qoratamu Godina Bale Itiyoopiya.

Waraqaan qulqullmaa ykn eeyyama qorannoo departimantii/muummee qulqullina naannoo UNISA, Oromiyaa akkasuma godina Bale irraa kan argamedha. Dabalatanis bulchinsa magaalotaa fi abbootii qabenya bishanii irraayis dursine eeyyama gafana. Yeroo odefannoon guramu kayyoo odeefanoo, fayidaa isaa, icitiin akka egamu durfame namootaaf akka ibsamuu fi eeyyamummaan isaniis durfame akka gaafatamuudha.

Erga kayyoon qu'annoo ibsamee fi booda eeyyamamummaan gaafatamtoota hunda ni mirkaneefam.

Kaayoon ijoon gaaffii kanaa dhimmaa qulqulummaa naannoo fi qulqulummaa bishanii magaalaa roobee fi gindhiir naannoo oromiyaa baha itoophiyaatti rakkoo ummata addaan baasuuf kan gaafatamuudha. Kanaaf bakka ga'uu qu'annoo kanaatiif gaheen keessan ol'aanaa waan ta'ef odeeffannoo sirri akka nuuf kenitan kabajaan isin gaafanna.

Odeeffannoo iddoo jirenya		
Guyyaa gaafin taasifame_____/_____/_____		Yeroo itti eegale
Naannoo	Godina	Aanaa
Magalaa	Ganda	Lakk. Mana

Gaaffilee

Lakk.	Gaaffii	Filannoo gaaffii	Irra uta ali
Gaaffilee dhimma hawaasummaa fi qabenyaa ilaalltu			
10 1	Umrii gaafatamaa	_____	
10 2	Saala	1. Dhiira 2. Dhalaa	
10 3	Amantaa	1. ortodoksii 2. Protestantii 3. Islaama 4. kan biro	
10 4	Sadarkaa barnoota gaafatamaa	1. Kan homaa hin baratin 2. Dubissu fi barreessu 3. Sadarkaa 1 ^{ffaa} 4. Sadarkaa 2 ^{ffaa} fi sana ol 5. Kan bira adda baasi_____	
10 5	Bay'inaa maati mana keessaa	_____	
10 6	Baay'ina daa'ima waggaa shanii gadii	_____	
Gaaffilee qabiinsa bishaanii waliin wal-qabatan			
201	Bishan kan argatan eessayyi?	1. Mada qulqulluu irraa 2. Madda qulqulluu hin ta'in irraa 3. Bishaan roobaa irraa	

		4. Tankarii iraa 5. Bishaan lafa gubaa(laga/hidha) 6. Haroo/boolla/madda/boo'ii/lolaa masnoo 7. Kan biro-----	
202	Bishaan hangam fayyadamtu?	1. Jarikana 1-5 2. Jarikana 6-10 3. Jarikana >10	
203	Yeroo hedduu bishan manaf kan warabu eenyu?	1. Hadha mana 2. Hojatu mana 3. Ijolllee 4. Kan biraa-----	
204	Gosa meeshaa bishaan itti waraabbatan(ilaali)	1. Huboo 2. Jarikana 3. Baaldii lastikaa 4. Baaldii sibiilaa 5. Kan biraa-----	
205	Yeroo bishaan waraabbii meshaan qadaada qabaa? (ilaali)	1. Eyyee 2. Miti	
206	Bishaan waraabuun dura harka kessan dhiqatanii?	1. Eyyee 2. Miti	
207	Itti waraabuun dura meshaa ni dhiqxanii?	1. Eyyee 2. Miti	
208	Bishaan dhugaatii fi kan biroo addaan	1. Eyyee 2. Miti	

	baaftuu? (dhiqaatii meshaa fi uffataa)		
209	Yeroo hangamiif bishaan warabdu?	1. Guyyaa tokko oluun 2. Guyyama guyyaan 3. Guyyaa lama lamaan 4. Kan biraa-----	
210	Bishaan mana keessatti ni kuufatu?	1. Eyyee 2. Miti	
211	Meeshaa kuusaa addaa ni qabduu?	1. Eyyee 2. Miti	
212	Gosa meeshaa itti kuufatanii. (ilaali)	1. Hubboo 2. Jarikanaa 3. Baldii lastikaa 4. Baaldii sibiila 5. Kan bira-----	
213	Meshaa kuusaa osoo itti hin kuusin dhiqxanii?	1. Eyyee 2. Miti	
214	Meshaa kuusaa qadaadamaa?	1. Eyyee 2. Miti	
215	Malli bishaan meeshaa keessa ittiin waraabataan	1. Buduruuysuu 2. Gadi qicuu	

	maali?		
216	Meshaan kuusaa keessa ittiin waraban gurra qaba?	1. Eyyee 2. Miti	
217	Meeshaa kuusaa keessa ittiin warabamu essa keettan?	1. Minjaala ykn sheelfii 2. Meeshaa kuusaa keessa 3. Qadaada kuusaa irra 4. Irratti rarraasuu 5. Lafa irra 6. Kan bira-----	
218	Bishaan kuusaa keessaa warabachuun dura harka keessan dhiqatuu?	1. Eyyee 2. Miti	
219	Naannoon meeshaa kuusaa qulqullummaa qaba? (ilaali)	1. Eyyee 2. Miti	
220	Carraan bineldonni meeshaa kuusaa bira ga'uu jira?	1. Eyyee 2. Miti	
221	Bishaan guyyaa hangamiif kuusama?	1. Guyyaa tokkoof sanaa gadi 2. Guyyaa tokkoo ol	

222	Bishaan waraabuun sa'aa hangam fudhata?	----- -	
223	Siinii faayda biraatiif itti fayyadamtuu?	1. Eyyee 2. Miti	
224	Yeroo bishaan kuusaa keessaa warabdan harki ni tuqaa?	1. Eyyee 2. Miti	
225	Meeshaan bishaan itti waraabame qadaada qaba?	1. Eyyee 2. Miti	
226	Bishaan fayida biraa dhugaatirraa adda jira?	1. Eyyee 2. Miti	
227	Yoo dhugaatiif warabdan harki tuqaa?	1. Eyyee 2. Miti	
228	Meeshaa kuusaa guyyaan dhiqamaa?	1. Eyyee 2. Miti	
229	Bishaan	1. Eyyee	

	qulqullesuuf yaaltuu?	2. Miti 3. Hin beeku	
230	Bishaan qulqullesuuf maal gootan?	1. Danfisuu 2. Kiloorinii itti dabaluu 3. Dhimbiibuu 4. Aduu keessa kaa'uu 5. Tursiisuu 6. Kan biro-----	
231	Balfaa garagaraa akkamitti baleesitu?	1. Mana qophaa'ina magalatiin 2. Gurmaa'ina dhunfaatiin 3. Karaa ykn iddoo irratti walitti qabamuu 4. Lagatti walitti qabuu 5. Gubuu 6. Kan biraa-----	
232	Bishaan isinirra hangam fagata?	-----	
233	Haalli tessuma bishaanii mana keessanirra akami?	1. Haala malee hin tolu 2. Hin tolu 3. Ni tola 4. Akka garii tola 5. Baay'ee tola	
234	Guyyatti bishan hangam warabbattu?	-----	
235	Bishaan hamma kana ga'aadha?	1. Gonkumaa ga'aa miti 2. Ga'aamiti 3. Hamma tokko ga'aadha 4. Ga'aadha 5. Akka gaaritti ga'aadha	
236	Bara dabre irraa	1. Gonkumaa	

	kaase galii ittiin galchuuf itti fayyadamtani?	2. Yeroo tokko tokko 3. Baay'inaan 4. Yeroo hunda	
237	Yeroo bishaan isisnii hojjatamu hirmaanna keessan akkam ture?	1. Gonkumaa 2. Gadi anaa 3. Gahaa 4. Garii 5. Baay'ee gaaridha	
238	Yoo hirmaatan ta'ee haala kamiin ture?	1. Humnaan 2. Mallaqaan 3. Meeshaa kennuun 4. Koree keessatti hirmachuun	
Haala sochii qulqulummaan wal-qabte			
301	Mana fincanii qabduu?	1. Eyyee 2. Miti	Yoo miti ta'e gara 302
302	Yoo mana fincanii hin qabne eessatti fayadamtan?	1. Handara irratti 2. Orruu qonnaa keessatti 3. Kan bir-----	
303	Mana fincaanii akkam qabdu?	1. Boolla salphaa 2. Kan afuura hin qabne 3. Kan bishan yaa'u qabu 4. Kan bira-----	
304	Fayyadamni mana fincanii	1. Yeroo hunda 2. Yeroo takka takka	

		3. Gonkuma	
305	Qulqullina mana fincanii	1. Gaaridha 2. Hanqina qaba	
306	Mana fincanii booda harka dhiqatu?	1. Eyyee 2. Miti	
307	Bishaan birka yoo jirate mana fincaanii irraa hangam fagaata?	1. 1-10 meetra 2. Meetira >10	
308	Balfa ni kuuftanii?	1. Eyyee 2. Miti	
309	Balfa eessatti kuusan? (ilaali)	1. Boola 2. Dirree irratti 3. Qaama bishaanii irratti 4. Gubuu 5. Akka xaa'ootti itti fayyadamuu 6. Kan bira-----	
310	Balfa akkamitti kuuftan?	1. Meeshaa qadada fayyadamu 2. Qadada kan hin qabne fayyadamu 3. Boola 4. Kan bira-----	
311	Namaa fi bineldonni iddo tokko jiraatu?	1. Eyyee 2. Miti	
312	Torbee lamaan	1. Eyyee	

	dabrite keessatti namni baasaan qabame jira?	2. Miti 3. Umrii-----	
313	Iddoo harka itti dhiqatan saamunaan jira?(ilaali)	1. Eyyee 2. Miti	
314	Ijolle wagga 5 gadii qabduu?	1. Eyyee 2. Miti	
315	Balfa daa'imani halaa kamiin gatan?	1. Daa'imni mana fincaanii fayyadama 2. Baaldii keessatti gatuu 3. Awwaaluu 4. Handaaratti gatuu 5. Kan biro-----	
316	Yoo mana fincaanii hin qabanne sababni maali?	1. Malaqqa dhabuu 2. Iddoo dhabuu 3. Eeyyama dhabuu 4. Manni kiraa waan ta'eef 5. Kan biro-----	
317	Guyya har'aa samuna qabduu?	1. Eyyee 2. Miti	
318	Sa'aa 24 dabre keessatti saamunaa fayyadamtanii?	1. Eyyee 2. Miti	

319	Samuna yeroo 24 dabre keessatti yoo fayyadamtan ta'e maaliif? (kan deebii itti mari)	1. Uffataan miicuu 2. Nafaan dhiqachuu 3. Harka daa'ima dhiquu 4. Nafa daa'ima dhiquu 5. Kan biro-----	
320	Yoo harka ni dhiqanna jedhan osoo deebii hin dubifneef kan deebisan irra mari.	1. Mana fincaanii booda dhiqachuu 2. Erga daa'ima qulqullesan 3. Erga daa'ima nyaachisan 4. Nyaata qopheesuun dura 5. Nyaata nyaatuun dura 6. Erga nyaatanii booda 7. Kan biro-----	
321	Harka dhiqachuun yoom barbaachisa? (deebii irra mari)	1. Nyata qopheesuu ykn bilcheesuu dura 2. Nyaachuun dura 3. Daa'imman nyachisuu dura 4. Mana fincaanii booda 5. Daa'iman qulqullesun boda 6. Nyaata booda 7. Kan biro-----	
322	Nafa eessatti dhiqatan?	1. Beenya qaba 2. Beenya ollattii fayadama 3. Mana dhiqana qaba 4. Kan ummatati fayyadama 5. Balditti dhiqadha	
323	Nafa yeroo hangamiin dhiqatta?	1. Guyyaa guyyaan 2. Akkuma barbaachseen 3. Torbanitt 4. Torbaan lamaan 5. Kan biro-----	

Galatoomaa!!!

IN-DEPTH INTERVIEW ABOUT:- Investigation of Drinking Water Quality,
Environmental Sanitation Practices and the Potential of Indigenous Plant Seed for
Purification in Southeast Ethiopia

Interview guide for an in-depth interview:

Good morning (afternoon); I would like to thank you & your institution for participating.

My name is _____ My colleague besides me is called _____

We came from Madawalabu University

This will be ready for them

We will conduct brief introduction and will talk about several different issues. We will ask you some questions about drinking water quality and environmental sanitation-hygiene practices

Potential use of Data

The information we are going to gather in relation to drinking water quality and environmental sanitation-hygiene practices will be utilized to design & implement successful implementation particularly in the zone in the near future.

Issues of Confidentiality

Please be certain that any information collected here is completely confidential. The research team or other participant will not directly share the gathered information in a way that would reveal an individual's personal identity.

Consent for participation and Tape –recording

It is necessary that we obtain your comment to conduct the session. Please understand that this is more for your protection than anything else.

Read Consent form loud to the key informant

You're remaining in this session indicates that you are a volunteer and agreed to participate for the discussion you have the right to refuse to answer any questions and end the discussion if you find it necessary to do so. For the sake of accuracy and efficiency, we will tape-record the sessions, unless there is an objection. This will be transcribed into text by similar language & will then be translated into the English language for summarization purpose.

Responsibility of the interviewer & Notetaker

The interviewer will forward the question one after the other was completed. The note Taker will be responsible to capture the information as accurately as possible. This will include not only participants' responses, but also nonverbal actions, physical environment, the atmosphere of the session as well as other important peculiar manifestations of that particular session. ***Importance of Key Informant Responses***

In this interview session you should feel free and talk freely. Each and every opinion/idea/ is important and wanted. It is vital that you get adequate time to express your idea (opinion). In this session, there is no wrong or right answer. You can express the opinion or attitude pertinent to you. When you express your opinion idea, you are encouraged to be honest in your view of drinking water quality and environmental sanitation-hygiene practices.

Now we would like to ask you the following questions about drinking water quality and environmental sanitation-hygiene practices

Table 27: Correlation Matrix:

Correlations											
		P ^H	TURBIDIT Y	TD S	CU ²⁺	Fe ²⁺	So ₄ ²⁻	No ₃ ⁻	Mn ²⁺	F ⁻	T ⁰ _C
P ^H	Pearson C	1									
	Sig. (2-tailed)										
TURBIDIT	Pearson C	.235	1								

Y	Sig. (2-tailed)	.513									
TDS	Pearson C	-.200	-.003	1							
	Sig. (2-tailed)	.580	.993								
Cu ²⁺	Pearson C	-.416	-.566	.705 [*]	1						
	Sig. (2-tailed)	.232	.088	.023							
Fe ²⁺	Pearson C	.518	.498	-.008	-.282	1					
	Sig. (2-tailed)	.125	.143	.982	.430						
So ₄ ²⁻	Pearson C	.031	.620	.728 [*]	.117	.471	1				
	Sig. (2-tailed)	.931	.056	.017	.748	.170					
No ₃ ⁻	Pearson C	-.147	.821 ^{**}	.237	-.160	.372	.638 [*]	1			
	Sig. (2-tailed)	.684	.004	.509	.660	.289	.047				
Mn ²⁺	Pearson C	-.430	-.677 [*]	.512	.765 ^{**}	-.217	-.006	-.425	1		
	Sig. (2-tailed)	.215	.031	.131	.010	.547	.987	.221			
F ⁻	Pearson C	-.466	.108	.799 ^{**}	.572	-.325	.579	.383	.296	1	
	Sig. (2-tailed)	.174	.767	.00	.08	.36	.08	.275	.40		

	tailed)			6	4	0	0		7		
T⁰c	Pearson C	.023	-.014	.86 2**	.51 0	.02 7	.63 5*	.127	.30 0	.5 07	1
	Sig. (2-tailed)	.950	.969	.00 1	.13 2	.94 1	.04 8	.726	.39 9	.1 35	
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

Procedures to clean water with *Moringa stenopetala* seeds

1. Collect mature *Moringa stenopetala* seed pods and remove seeds from pods.
2. Shell seeds (remove seed coat) to obtain clean seed kernels; discard discolored seeds.
3. Determine quantities of kernels needed based on amount and turbidity of water; in general 1 seed kernel will treat 1 liter of water.
4. Crush appropriate number of seed kernels (using grinder, mortar & pestle, etc) to obtain a fine powder and sift the powder through a screen or small mesh.
5. Mix seed powder with a small amount of clean water to form a paste.
6. Mix the paste and 250 ml (1 cup) of clean water into a bottle and shake for 1 minute to activate the coagulant properties and form a solution.
7. Filter this solution through a muslin cloth or fine mesh screen (to remove insoluble materials) and into the water to be treated.
8. Stir treated water rapidly for at least 1 minute then slowly (15-20 rotations per minute) for 5-10 minutes.
9. Let the treated water sit without disturbing for at least 1-2 hours.
10. When the particles and contaminants have settled to the bottom, the clean water can be carefully poured off.
11. This clean water can then be filtered or sterilized to make it completely safe for drinking.

Dosage Rates:

Low turbidity NTU<50 1 seed per 4 liters water

Medium turbidity NTU 50-150 1 seed per 2 liters water

High turbidity NTU 150-250 1 seed per 1 liter water

Extreme turbidity NTU >250 2 seeds per 1 liter water

University of South Africa in partnership with SANTRUST
'The PhD Proposal Development Programme'

This is to certify that

Ahmed Yasin Mohammed

*has completed the following formative modules in the
'PhD Proposal Development Programme':*

- *Idea formation, Working with Theories, Theoretical Frameworks and Fundamentals of the Literature Review*
- *The Research Question and Sub-Questions: An approach*
- *Research Design: Quantitative and Qualitative Methods*
- *Quantitative and Qualitative Methods*
- *Ethics for Research*
- *Academic Writing*
- *Essentials of Project Management for the Proposal and Dissertation process*
- *Analysis of Data: Quantitative and Qualitative*
- *Mentoring and Dissemination*
- *Composing and defending the research proposal*



Dr A Padayachee
CEO of SANTRUST

24 November 2011

University of South Africa in partnership with SANTRUST 'Student Record on PhD Proposal Development Programme'

P.O. Box 1592, Mount Edgecombe, www.santrust.org.za / Medium of Instruction: English / Certificate Awarded: November, 24, 2011

Full Name : **Ahmed Yasin Mohammed**

Module	Course Title	Duration Notional Hours
1	Idea formation, Working with Theories, Theoretical Framework and Literature Review, Project Management	70
2	The Research Question and Sub-Questions, An approach, Academic Writing	60
3	Research Design: Qualitative and Quantitative	60
4	Research Methodologies: Qualitative and Quantitative methods, Ethics for Research	60
5	Analysis of Data: Qualitative and Quantitative; Polishing of Proposals and Presentation Skills	120
6	Composing and Defending Research Proposal	180
Academic Writing, Mentoring and Dissemination & Developing a Scholarly Identity: mainstreamed in the programme		
Total Hours		550



Dr A Padayachee
CEO of SANTRUST

24 November 2011



Biiroo Qabeenya Bishaan Oromiyaattii
Tajaajila Bishaan Dhugaattii fi
Dhangala'aa Magaalaa Balee Roobee
በኢትዮጵያ ውስጥ በፖለቲካ ምክር ቤት
ወጥሶ ምክር ቤት አባልነት አግኝቶ

NO. 12811/1347/2005

Date: 12/3/2005
Nov. 26/2012

LETTER OF PERMISSION

We are giving this permission letter for Mr. Ahmed Yasin Mohammed who is a lecturer at Madawalabu University College of Medicine and Health Sciences and UNISA PhD Student to conduct his research in our town to collect data and water sample for his research title: Bacteriological; Physicochemical Quality of Drinking Water and Sanitation- Hygiene Practices of Consumers :Indigenous Plant Seed as Alternative In Purification of Drinking Water In South East Ethiopia; Oromia Regional State Bale Zone Robe Town. He also informed as the purpose and procedure of the study. So, we permitted him to collect data and conduct the research. We are also very happy to encourage this research since the research problem is our local community problem. Therefore the research process will not have any negative impact on the research subjects and on the quality of the environment. So, we are very sure to inform you that the finding of this research will improve our local Community (Robe Town) problem of drinking water quality and sanitation-Hygiene practices.

With best regards

Baqqalaa Araarsaa Badhaasaa
ATA 66-CA 054
Abbaa Adcemsaa Hojii
የሥራ ሂደት መሪ



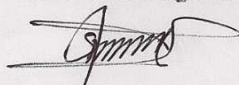

Bureo Obeesha Bishaan Oromiya
 Tajaajila Bishaan Dhugaatii fi
 Dhaaga'aa Mazaalaa Jindhiir
 በኢትዮጵያ ውስጥ የሕይወት ጥበቃ
 ዘመን ውስጥ የሕይወት ጥበቃ

NOV. 28, 2012
 NO. B.38/1865/105
 Date 19/3/105

LETTER OF PERMISSION

We are giving this permission letter for Mr. Ahmed Yasin Mohammed who is a lecturer at Madawalabu University College of Medicine and Health Sciences and UNISA PhD Student to conduct his research in our town to collect data and water sample for his research title:-Bacterological;Physicochemical Quality of Drinking Water and Sanitation- Hygiene Practices of Consumers :Indigenous Plant Seed as Alternative In Purification of Drinking Water In South East Ethiopia; Oromia Regional State Bale Zone Ginnir Town . He also informed us the purpose and procedure of the study. So, we permitted him to collect data and conduct the research. We are also very happy to encourage this research since the research problem is our local community problem. Therefore the research process will not have any negative impact on the research subjects and on the quality of the environment. So, we are very sure to inform you that the finding of this research will improve our local Community (Ginnir Town) problem of drinking water quality and sanitation-Hygiene practices.

With best regards



Tasfaye G/Madihin G/Tsadiq
 ተሳፋሪ ገ/ማዳከን ገ/ጽዳቅ

Ab/Ad/H/Faas!!!!!!
 Dhiyessa Bishaan
 የመጠጥ ውሳኔ አገልግሎት
 ክፍል 346





የኢትዮጵያ የተስማሚነት ምዘና ድርጅት
Ethiopian Conformity Assessment Enterprise

ቁጥር (No.) 4/1/135/2012

ቀን (Date) 30 NOV 2012

TO: University of South Africa (UNISA)
Pretoria

SUBJECT: Declaration of the Granting of Permission

Referring to the application letter submitted to our organization on 27 November, 2012 Ref.No. Rmu.17.172610, by PhD Student Ahmad Yasin Mohammed for his PhD research title:- Bacteriological, Pysicochemical quality of Drinking Water :Indigenous Plant Seed as alternative in purification of Drinking Water in South East Ethiopia with Unisa ID 45595291, requesting for experimental test/analysis service at our laboratory, we certified him that we can do experimental test/analysis of Pysicochemical and microbiological on Drinking Water as per our organization rules and regulation set on payment basis.

We wish the researcher best experimental results and success.

Best regards,

Tesfaye Solomon
Head Branch Coordination and Customer's Service

CC. ECAE

- Branch Coordination and Customer's Service
Addis Ababa

ወደ ላቀ ብቃት የሚያደርስዎ!
Moving you forward!

Head Quarters
House No: New:
Woreda 6 Bole Sub city
P.O. Box: 11145
Addis Ababa, Ethiopia
Tel: +251 (011) 646 0569
Fax: +251 (011) 645 9720
Email: info-ep@eca-e.com
(Complain Handling)
Web site: www.eca-e.com
Bank Acc.

Director General Office
Tel: +251 (011) 646 0569
Fax: +251 (011) 645 9720
Email: info-dg@eca-e.com

Customer Services
Tel: +251 (011) 651 6468
Fax: +251 (011) 645 9308
Email: info-cs@eca-e.com

Certification Services
Tel: +251 (011) 646 0548
Email: info-cd@eca-e.com

Inspection Services
Tel: +251 (0)
Email: info-id@eca-e.com

Testing Laboratory Services
Tel: +251 (011) 646 0683
Email: info-td@eca-e.com

Corporate Communication
Tel: +251 (011) 651 1381
Email: info-cc@eca-e.com

Addis Ababa Branch
Tel: +251 (011) 515 3133
Fax: +251 (011) 440 0627
Email: addisababa-br@eca-e.com

Central Branch (Adama)
Tel: +251 (022) 111 2278
Fax: +251 (022) 112 8066
Email: adama-br@eca-e.com

Southern Branch (Hawassa)
Tel: +251 (046) 221 4732
Fax: +251 (046) 220 4488
Email: hawassa-br@eca-e.com

North Western Branch (Bahir Dar)
Tel: +251 (038) 220 0724
Fax: +251 (038) 220 0724
Email: bahirdar-br@eca-e.com

North Eastern Branch (Dessie)
Tel: +251 (033) 111 1664
Fax: +251 (033) 111 9069
Email: dessie-br@eca-e.com

Eastern Branch (Dire Dawa)
Tel: +251 (025) 111 3159
Fax: +251 (025) 112 1426
Email: diredawa-br@eca-e.com

Northern Branch (Mekele)
Tel: +251 (034) 440 6280
Fax: +251 (034) 440 6280
Email: mekele-br@eca-e.com

Western Branch (Jimma)
Tel: +251 (047) 111 4332
Fax: +251 (047) 111 7020
Email: jimma-br@eca-e.com



Lakk./ቁጥር/ Ref. No. BBA/19.1/86
Guyyaa /ቀን/Date 30-11-2012

To:- **University of South Africa(UNISA)**

Subject:- Declaration of the Granting of Permission

Referring to the application letter submitted to our office on 28 November, 2012, by PhD student Ahmad Yasin Mohammed for his PhD research title:- Bacteriological; Physical Quality of Drinking water and sanitation –Hygiene practices of Consumer: Indigenous plant seed as alternative for purification of Drinking water in South East Ethiopia with Unisa ID 45595291, Requesting for Experimental Tests/ Analysis Service at our laboratory, we certified him that we can allow him to do and do experimental test/analysis of physical chemical and Bacteriological on drinking water as per our laboratory rules and regulation.

We wish the researcher best experimental results and success.



With Compliment,

Daba Dhuguma Waml
Head, Water Supply Facilities
Management Process



*T/C 231/22.05/1189
Ref. No.
ቀን 29/11/2012
Date

To: University of South Africa (UNISA)

From: Addis Ababa Environmental Protection Authority

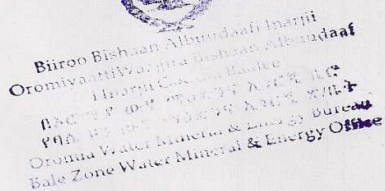
Subject: Declaration of the Granting of Permission

Referring to the application letter submitted to our office on 27 November, 2012, by PhD Student Ahmad Yasin Mohammed for his PhD research title:- Bacteriological; Physical Quality of Drinking water and sanitation-Hygiene practices of Consumer: Indigenous plant seed as alternative for purification of Drinking water in South East Ethiopia with Unisa ID 45595291, *Requesting for Experimental Tests/Analysis* service at our laboratory, we certified him that we can do experimental test/analysis of physical chemical and Bacteriological on drinking water as per our laboratory rules and regulation set on payment basis.

We wish the researcher best experimental results and success.

With Compliment,


Aduana Mekonnen Beyene
City Manager and Head for
Environmental Pollution & Impact
Monitoring & Control Core Process

Date 17/03/05
Nov. 26/2012

We are giving this permission letter for Mr. Ahmed Yasin Mohammed who is a lecturer at Madawalabu University College of Medicine and Health Sciences and UNISA PhD Student to conduct his research in our town to collect data and water sample for his research title:-Bacteriological;Physicochemical Quality of Drinking Water and Sanitation- Hygiene Practices of Consumers :Indigenous Plant Seed as Alternative In Purification of Drinking Water In South East Ethiopia; Oromia Regional State Bale Zone Ginnir Town and Dire Shekhussien . He also informed us the purpose and procedure of the study. So, we permitted him to collect data and conduct the research. We are also very happy to encourage this research since the research problem is our local community problem. Therefore the research process will not have any negative impact on the research subjects and on the quality of the environment. So, we are very sure to inform you that the finding of this research will improve our local Community (Ginnir Town and Dire Shekhussien) problem of drinking water quality and sanitation-Hygiene practices.

Adam Abdul-Qadir

Deputy Office Head

